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APALACHICOLA BAY DREDGED

MATERIAL DISPOSAL PLAN

Funding for this project was provided by the
National Oceanic and Atmospheric Administration
through the Office of Coastal Management,
Florida Department of Environmental Regulation,
under the Coastal Zone Management Act of 1972, as amended

Steve Leitman, Kathleen Brady, Lee Edmiston,
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Fl. - Dept of Environmental Regulation

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DEPARTMENT OF ENVIRONMENTAL REGULATION
STATE OF FLORIDA

July, 1986

ACKNOWLEDGEMENTS

I wish to acknowledge the assistance of all the staff who helped prepare this document including Wayne Ashmore and Carol Knox for graphics; Susan Parks, Pam Wiley, Patty Lee and Sophia Chambers for secretarial help; Jim Stoutamire for managing grant monies; and Pam McVety for her guidance and trust. I also want to thank Dr. R.J. Livingston and Dr. J. Donoghue, Florida State University; Woody Miley and Joseph Thompson, Florida Department of Natural Resources; Lou Burney and Leslee Williams, Florida Department of Environmental Regulation; DeWayne Imsand and Harry Peterson, U.S. Army Corps of Engineers; Dr. Robert Ingle; and many residents and fishermen of Franklin County for their guidance and assistance in preparing this report.

Steve Leitman

Project Administrator

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I. INTRODUCTION

This document was prepared to ensure 1) that navigation channels in Apalachicola Bay are maintained in a manner which minimizes environmental degradation of the estuarine ecosystem, and 2) that permits to maintain navigation channels in the bay are obtained in an expedient manner. Development of this plan was required by a series of conditions agreed upon between the States of Alabama, Florida, and Georgia when the lower Apalachicola River and Bay was designated as a National Estuarine Sanctuary in 1979. These conditions resulted from concerns expressed by the States of Alabama and Georgia, and waterway navigation interests that the State of Florida could obstruct navigation on the Apalachicola River through the designation as an Estuarine Sanctuary. The conditions agreed upon by the three states were:

(1) that the State of Florida issue a five-year dredging and spoil disposal permit to the U.S Army Corps of Engineers (COE) for the entire length of the Apalachicola River;

(2) that COE navigation requirements be incorporated into the five-year permit if they are in compliance with Florida law;

(3) that Florida pursue a Level B study with the COE and the States of Georgia and Alabama to evaluate the water resources in the Apalachicola-Chattahoochee-Flint (ACF) River system;

(4) that the State of Florida initiate and develop a long-

term spoil disposal plan for the Apalachicola River and Bay in cooperation with the COE before the expiration of the five-year permit and;

(5) that Florida work out a memorandum of understanding in cooperation with the COE to evaluate steps that can be taken to increase the availability of a 9 x 100 foot channel up the Apalachicola River.

With completion of this plan all of these conditions have been met.

Because of the dynamic nature of estuaries, and progress in estuarine research, this plan should be reviewed and amended at least once every five years. Review and updating is the responsibility of the Florida Department of Environmental Regulation (DER) and will be coordinated with the COE, Mobile District and other state and federal agencies. If studies or additional information dictate that the plan should be changed more frequently, it shall be the responsibility of the DER to implement the changes.

The purpose of this plan is to provide guidelines for the COE to maintain the authorized navigation channels in Apalachicola Bay in a manner acceptable to the State of Florida. This plan was developed by first preparing the technical support sections (i.e., the main body of the report) which focus on how the estuary functions ecologically, what the needs of authorized navigation projects are, and how dredging and disposal disposal activities can impact estuaries in general and the Apalachicola system specifically. This support document was then sent out for an extensive review process. Once consensus was reached on the support document, a set of conclusions were derived, and a set of operating policies and accompanying implementation strategies developed to address each conclusion.

Since this plan is being developed for maintenance of channels which already exist, a major emphasis of this effort was to define how past practices have affected the ecology of the estuary on both a localized and system-wide basis. Existing disposal practices represent the most economical means for maintaining the channels. Therefore, staff did not feel it was appropriate to recommend alternatives to existing practices unless significant impacts could be documented, or unless the impacts associated with an activity were highly probable and of an unacceptable level. Emphasis was placed upon modifying existing disposal methods as necessary and upon identifying data gaps which need to be addressed to provide the necessary information for a comprehensive understanding of the dredge and disposal impacts upon Apalachicola Bay. If future studies indicate there is significant impact from existing practices, alternative disposal options will be sought at that time.

II. CONCLUSIONS AND GUIDELINES FOR THE DISPOSAL OF DREDGED MATERIAL IN APALACHICOLA BAY.

The following conclusions, operating policies and implementation strategies were developed in response to an evaluation of the impacts of dredging and disposal practices in the Apalachicola estuary. A more detailed presentation of the supporting information which accompanies each conclusion may be found in the main body of the report.

CONCLUSION 1

Many of the studies evaluating environmental impacts of dredging and disposal practices in Apalachicola Bay are inadequate for determining the extent of ecological impacts. The institutional process for designing studies, assuring quality control, reviewing results, and integrating studies into operational programs has also been inadequate.

Discussion

Because of the complex nature of estuaries, problems are frequently encountered in conducting research in these ecosystems. Statistical verification, comprehensive project design, and interpretation of results often present substantial obstacles for researchers and thereby inhibit attempts to document long-term impacts. As a result of this complexity, there is too often an omission of some aspect of the project design that does not become apparent until after sampling has begun, or after the research project is completed. Furthermore, it is important to understand the complex interactions of the physical, chemical, biological and geological processes for a complete understanding of an estuarine system. Interdisciplinary investigations are therefore important, although many studies in the system to date have not been of an interdisciplinary nature.

In reviewing previous research projects associated with the impacts of dredging in Apalachicola Bay there were problems noted in the design, control, and review of the studies. Most of the existing studies were designed not to assess if impacts had occurred, but to evaluate readily apparent potential impacts. Most were also broadly designed attempts to answer numerous questions in one single study effort. Because of funding limitations biological study efforts designed to assess the impacts of channel maintenance on the estuary have had limited sampling periods and too few samples collected. Yet, these studies have been used to make broad conclusions with regard to the level of impact. The only biological data which is of a long-term nature was not designed to determine impacts except on a gross, system-wide basis. A detailed physical data base has been collected to develop a hydrodynamic model of the estuary. However, funds have not been released to analyze this data base. Consequently, this data base has not been adequately integrated into the decision-making process. Therefore, at present there is not an adequate information base to allow a conclusive determination to be made of whether significant impacts have occurred, or may be expected to occur from dredge and disposal activities. To date, no major impacts on the Apalachicola Bay ecosystem from dredging and disposal activities have been documented.

Furthermore, no adequate review procedure has been set up to ensure that studies are properly designed and conclusions are well supported. Much of the monitoring data collected by the COE has not been routinely evaluated to interpret its findings by either the COE or DER. No procedure for review of studies by scientists outside the government has been established. And, no formalized procedure has been established to integrate research findings into operational programs. In the past few years there has been progress on improving interagency coordination on study efforts. During preparation of the Sikes Cut Study, the Navigation Maintenance Plan, and the Bay Water Needs Study extensive coordination occurred in both designing and conducting the studies. However, no formalized procedures have been adopted to assure that such a coordinated program will continue in the future.

Operating Policy 1-I

Continued evaluation of the localized and system-wide impacts from maintenance dredging and disposal activities in Apalachicola Bay is necessary.

Implementation Strategy 1-I

Continued analysis and research can be accomplished by permit conditions, assessments by the COE, joint studies by the DER and the COE, and studies conducted or funded by other agencies or groups. Incorporation of necessary studies as permit conditions and requiring interagency coordination on these studies has been a standard practice for several years. The DER will conduct a meeting in Fall 1986 to discuss and reach conclusions concerning the need for and scope of future research and monitoring efforts.

Operating Policy 1-II

The DER, in conjunction with interested agencies (such as the COE and the Apalchicola National Estuarine Reserve) shall estab- lish and maintain a procedure to design and oversee studies and monitoring efforts in Apalachicola Bay.

Implementation Strategy 1-II

A formal program should be established to be used as a standard tool for the design and management of future studies and monitoring efforts in Apalachicola Bay. This can be accomplished through establishing a task force which:

a) utilizes an interdisciplinary approach to incorporate personnel with the expertise necessary to properly design and oversee particular studies and monitoring programs;

b) focuses upon achieving realistic, well defined objectives for each individual effort;

c) requires appropriate quality control for each project;

d) designates a schedule for interim and final reports;

e) utilizes the guidelines outlined in "Deepwater Ports Maintenance Dredging and Disposal Manual" (Ryan, et al.,1984) to design monitoring programs and define informational needs.

Operating Policy 1-III

The DER, in conjunction with interested agencies, shall establish and maintain a systematic procedure to evaluate studies and monitoring data, and incorporate pertinent results into permits and management actions.

Implementation Strategy 1-III

This operating policy shall be implemented through:

a) sending all monitoring data and reports required by DER permits to appropriate parties to be reviewed and evaluated through a written review;

b) the DER and the COE meeting at least once each year to assess the maintenance program for navigation channels in Apalachicola Bay, determine if any research findings should be incorporated into the dredging and disposal program, and determine what future studies or monitoring efforts are warranted;

c) the COE and the DER providing each other with the option of prior review for all projects, studies and monitoring efforts related to the Apalachicola Bay system. The review should be conducted at the earliest possible date, with adequate time provided for an in-depth review.

At present, some of these actions are being done, however this is on an ad hoc, informal basis.

CONCLUSION 2

The potential impacts of dredging and disposal activities are variable and depend upon many physical and biological factors including circulation patterns, sediment characteristics proximity to sensitive areas, proximity to pollution sources, and time of the year.

Discussion

Due to the complex and dynamic nature of estuaries, and because the behavior of dredged material is dependent upon the sediment characteristics and hydrography of the area where dredge and disposal activities occur, the impacts from a dredging event depend on when and where the dredging event occurs as well as the specific practices employed. Therefore, dredging and disposal practices should be determined on a site-specific basis. Further, monitoring and management programs should be designed on a site specific basis. They should also be linked to specific management and research goals.

Because of the complex interactions between physical, chemical, biological, and geological processes, variations in parameters such as salinity, temperature, sediment characteristics, chemical constituents and current velocities result in different environmental responses when dredging events are seperated either spatially or temporally. One example of the variability of processes within the estuary is current velocity. Current velocities are highly variable both temporally (spring versus neap tides) and spatially (passes versus central bay or river-mouth sites). Current velocities have a considerable affect on the size and transportation of turbidity plumes caused by dredge and disposal activities. Wind is another important variable in transporting turbidity plumes and in the resuspension of dredged material. Wind also affects current directions and velocity and is highly variable.

Sediment quality is another example of the variable nature of estuarine constituents. The grain-size distribution of bottom sediments is dominated by sand in one part of the estuary, and clay in another. Grain-size distribution is an important factor in defining the degree of impact from a dredging event. Finer grained sediments are more readily suspended and circulated throughout the estuary, and have a greater affinity for organic and inorganic substances. Therefore, dredging of finer grained sediments has a greater potential to cause adverse impacts.

The release of substances to the water column is also dependent upon chemical characteristics which vary within the estuary. For instance, the pH value affects the solubility, degree of complexation, and sorption of solutes by particulate matter. Therefore, the mobility of many substances from the sediments to and from the water column varies with the pH. For example, the solubility of ferrous iron is about 100,000 times greater at pH 6.0 than at pH 8.5. Chemical characteristics are often exhibited as lateral and/or vertical gradients within the estuary. These gradients and the influences exerted by interactive processes upon the dredged material need to be better understood. In addition to physical, chemical and geological characteristics, seasonal biological variations such as reproductive season and timing of migrations and juvenile habitation need to be taken into consideration.

Operating Policy 2-I

Monitoring efforts shall be conducted in a coordinated manner and designed with consideration to the specific project needs.

Implementation Strategy 2-I

Monitoring efforts specified by permit conditions shall be designed by a task force which shall:

a) have as a long term goal the evaluation of impacts upon habitats and organisms caused by specific environmental perturbations (including sub-lethal and cumulative impacts);

b) utilize the best available information in the design, collection methodologies, and analytical techniques;

c) coordinate monitoring design with previous monitoring efforts;

d) use as a baseline for monitoring programs the general protocol, methodologies, and interpretive framework outlined in Ryan, et al. (1984), and DER (1986, 1986a);

e) require written reports of monitoring data utilizing a standard format for each monitoring effort;

f) designate a location for storing monitoring reports and studies;

g) consider specific monitoring needs necessary to properly evaluate different dredge and disposal projects;

h) consider the possibility of a joint monitoring effort by the COE and the DER;

i) incorporate a permanent oyster bed and seagrass bed monitoring plan;

j) designate persons with whom the monitoring team should consult on a regular basis;

k) contain an explicit description of field collection techniques developed in coordination with the DER.

CONCLUSION 3

Material at open-water disposal sites in Apalachicola Bay migrates off of the site both during the dredging event and for months afterwards. Therefore, the area of impact extends beyond the disposal site boundaries.

Discussion

At open-water disposal sites disposal material is removed from the site over time. This occurs initially during the dredging event when suspended material is transported from the disposal site in a turbidity plume. In the intermediate period, the finer particles which are not transported away in the plume settle out above the larger particles in a highly concentrated layer, forming a "fluid mud." The fluid mud spreads out, often beyond the disposal area, and is eventually dispersed by waves, wind, currents and gravity. Over time, additional material at the disposal site is resuspended by natural processes and transported off the disposal site. Both the turbidity plume and the transportation of the fluid mud result in higher suspended sediment levels on a localized basis. Because increased suspended sediments decreases the depth of the photic zone, it has the potential to directly and indirectly impact the primary and secondary productivity of the bay. The ultimate fate of the clays and fine organics that migrate off the disposal site need to be understood. It must also be understood that the bay is a naturally turbid system.

Although the COE contracted with the U.S. Geological Survey to gather data to determine the extent of the fluid mud migration, the study did not address the ultimate fate of the material, its contribution to levels of suspended sediments and turbidity within the bay, or its subsequent impact on biota.

Operating Policy 3-I

Oyster bars, seagrass beds and other susceptible habitats shall be protected from impacts from dredging and disposal activities.

Implementation Strategy 3-I

No permit shall be issued for dredging or disposal activities before oyster bars, seagrass beds, and other susceptible habitats within one mile of a dredge or disposal site have been adequately surveyed, and plans and conditions for monitoring the habitats before, during, and after the project have been made. Any documented impacts shall be corrected by modifying the dredge and disposal activities and/or appropriate mitigative actions.

Operating Policy 3-II

The fate of dredged materials should be determined particularly with respect to fluid muds, resuspended materials and their impacts upon the ecology of the bay.

Implementation Strategy 3-II

The fate of fluid muds, and the extent and impact of resuspended material in general should be studied further. This could be accomplished as a permit condition. Since gravity causes the fluid mud to "flow", dredge operators should be required, through permit conditions, to minimize mounding of the disposal material.

CONCLUSION 4

The potential ecological impacts from dredging and disposal activities, and the rate of habitat recovery vary seasonally.

Discussion

The vulnerability of most species in Apalachicola Bay to dredging impacts varies seasonally with the timing of reproduction, larval recruitment and juvenile habitation. Populations are lower during the winter months because of the offshore migration of many species. In addition, the bay is more heavily utilized by juvenile estuarine organisms in the spring, summer and fall quarters. This is especially true for the commercially important fish, shrimp, and crabs. Although oysters do not migrate, they too are more susceptible to dredging impacts in the spring, summer, and fall months, because the oyster spawning season is from April through November. The spat are planktonic and must settle out on a hard surface to survive. Galtsoff (1964) has demonstrated that one millimeter of sediment covering cultch material will prevent the spat from setting. Additionally Loosanoff (1961) showed that silt levels as low as 250 mg/l will significantly affect the development of oyster eggs. Seagrasses would also be affected less by winter dredging since it is their least active growth period.

Operating Policy 4-I

Dredging in the Apalachicola estuary shall be restricted to the winter season.

Implementation Strategy 4-I

Except for emergency situations, no permit shall be issued for dredging in Apalachicola Bay outside of the winter season (December 1 through March 15). Modifications to the recommended time frame, or exemptions for a specific project from the time frame, may require the applicant to perform studies or to participate in mitigative activites as determined necessary by the DER.

CONCLUSION 5

Salinity, circulation patterns and flushing rates are key variables in defining the community structure of the estuary.

Discussion

The biological productivity of Apalachicola Bay is the result of certain physical parameters, such as nutrient input from the Apalachicola River, the salinity regime and circulation patterns as defined by the tides, winds and geometry of the estuary. Circulation patterns in the estuary carry sediments, nutrients and freshwater which determine habitat quality and biological community structure. Therefore, circulation is an important factor in defining the ecological organization of the estuary.

Open-water disposal of dredged material in Apalachicola Bay can result in altered hydrological conditions. Bathymetric changes due to dredging and disposal can affect the current velocities, circulation patterns, salinity, temperature, and erosion and deposition patterns. These changes, in turn, would affect the biota. Likewise, the construction and maintenance of inlets alters the salinity regime in the estuary, and therefore affects the biota.

If the variables affecting salinity regimes and circulation patterns in Apalachicola Bay are understood, management activities can be conducted more effectively. In an attempt to understand the long term physical and ecological effects several mathematical models of the estuary have been developed. The most recent of these models is being used in several ongoing study efforts to assess management options.

Operating Policy 5-I

Any permits for modifications of existing navigation projects or proposed new projects (i.e., additional channels, deepening of existing channels, disposal islands, etc.) shall include an evaluation of the effects on circulation patterns, flushing rates and salinity changes before issuance of the permit. The impacts from existing projects should also be documented.

Implementation Strategy 5-I

In reviewing permits for federal or state actions in the Apalachicola Bay system the DER shall require a detailed analysis of the impacts of the project on circulation patterns and the salinity regime. Documentation of the impacts from previous and proposed dredging and disposal activities should be determined through use of the two-dimensional hydrodynamic model.

Operating Policy 5-II

The effects of the existence and maintenance of the St. George Island Channel (Sikes Cut) on the salinity regime and circulation patterns of Apalachicola Bay needs to be well defined. The long-term maintenance program for the Cut needs to be based on the results of this study.

Implementation Strategy 5-II

An on-going study of the ecological impacts of the existence and maintenance of Sikes Cut is currently under way. This analysis is utilizing a two-dimensional model and is being managed in coordination by the DER and COE. Results of this study will be used to evaluate management options.

CONCLUSION 6

Dredging of the Eastpoint Channel has the potential to significantly damage estuarine habitat because of the migration and resuspension of material, and its proximity to productive oyster bars.

Discussion

Data show that the Eastpoint Channel has high levels of oils and greases, nutrients, and heavy metals in the sediments. The sediments in the channel also tend to be of a finer nature. Since the Eastpoint Channel is close to highly productive oyster beds (about 1,300 feet from Cat Point which is currently the most productive bar in the estuary) and the prevailing current direction is towards these beds, the potential for burial or contamination of these beds exists. The permit for the Eastpoint Breakwater allows for dredged material to be disposed of at an open-water site on a one time basis and for the subsequent monitoring of this event. However, since the Eastpoint Channel has not been dredged since 1979, the next dredging event during which this evaluation is to take place will be much larger than previous dredging events and events that would be typically expected to occur in the future. Therefore, the potential impacts of this event are also anticipated to be much larger than previously experienced.

Operating Policy 6-I

Alternative disposal methods should be utilized for the Eastpoint Channel.

Implementation Strategy 6-I

Alternative disposal options including upland disposal, ocean disposal, diked island disposal, and the option of foregoing the project should be assessed in detail. The most feasible alternative should become the disposal method for the Eastpoint Channel.

CONCLUSION 7

The methods and techniques used during dredging and disposal operations are determinants of the severity of impacts.

Discussion

Several investigators have noted that the dredging and disposal methods and techniques utilized have differing effects on the associated levels of impacts (Schubel, 1978; Huston and Huston, 1976). Some of the factors that influence the extent of the environmental impacts include: the quantity of material (total yardage); the rate of disposal (cubic yds./hr); the duration and frequency of recurrence of dredging; the ratio of sediment to water being pumped; the location of dredging and disposal sites; the geometry of the deposited material; the methods of excavation, transport and disposal; and type of material. The effects of different methods and techniques will also vary with the chemical and physical nature of the sediment being moved and circulation patterns.

Operating Policy 7-I

Alternative methods and techniques for dredging and disposal activities should be further evaluated .

Implementation Strategy 7-I

Further information should be collected on the degree of environmental perturbation resulting from alternative open-water disposal methods and techniques in Apalachicola Bay. Some evaluations along these lines have already been conducted by the COE. Once this information is developed a report should be prepared addressing the suitability of each method and technique to the Apalachicola estuary. This evaluation should consider the extent of impacts with varying sediment types, waves, and current regimes typical of the bay. The report should also review alternative uses for the dredged material such as oyster bed and seagrass bed creation and should be done as a joint effort between DER, COE and other agencies.

Operating Policy 7-II

The height at which material is disposed of at open-water sites shall not exceed mean low water levels unless specifically permitted as such.

Implementation Strategy 7-II

Permits for disposal of dredged material in Apalachicola Bay shall require that disposed material not be deposited above mean low water levels. Bathymetric surveys of the anticipated disposal impact area should be required before and after disposal activities (preferably just prior to, as soon as possible after (i.e., two to three days), and 2-3 months after disposal).

CONCLUSION 8

A comprehensive program for mitigating environmental impacts and permit violations associated with dredge and disposal activities in Apalachicola Bay should be developed and implemented.

Discussion

Apalachicola Bay has been determined to be an area of significant state and national interest. The bay has been designated as a National Estuarine Reserve by the federal government, and as an Aquatic Preserve, Outstanding Florida Water, and an Area of Critical State Concern by the State of Florida. The recognized importance of the area also led to the development of this plan. The bay is also an important economic asset both to the state and to Franklin County.

There have been problems in the past both with obtaining necessary permits, and with the permits that are ultimately issued. The fact that many of the authorized channels have not been permitted since 1979 documents this. An example of a problem with permit conditions relates to the fact that although open-water is the permitted disposal practice for the GIWW, there are no height restrictions in the permit for open-water sites. As a result, the permit allows material to be piled above mean low water. Therefore, island creation at an open-water site is not a violation of the current permit.

Operating Policy 8-I

Dredge and disposal techniques used in Apalachicola Bay shall be consistent with the state-of-the-art techniques for minimizing impacts. Permits should clearly specify techniques allowed, type of disposal permitted, limitations on use of the site, and responsibility and enforcement procedures for permit violations.

Implementation Strategy 8-I

Permits should be written such that all parties understand precisely what is allowed under the permit. The DER should make it a priority to incorporate the Operating Policies and Implementation Strategies in this plan and the findings of future monitoring efforts into the maintenance dredgiong program for the estuary.

Operating Policy 8-II

Permits for dredge and disposal operations in Apalachicola Bay shall incorporate appropriate mitigative activities to minimize negative environmental impacts.

Implementation Strategy 8-II

The COE, DER, DNR, U.S. Fish and Wildlife Service and National Marine Fisheries Service should meet to agree upon mitigation procedures and which mitigation actions are appropriate for the Apalachicola Bay system. One mitigative activity which should be considered in this meeting is habitat creation and/or restoration, including creation of seagrass beds, salt marshes and oyster bars. When possible, it would be ideal to use disposal material in habitat creation. Use of dredged material for roadfill or other approved upland uses should also be investigated.

III. ENVIRONMENTAL SETTING

The Apalachicola-Chattahoochee-Flint (ACF) basin covers the north-central and southwestern part of Georgia, the southeastern portion of Alabama, the central portion of the Florida panhandle, and terminates in Apalachicola Bay. Figure 1 shows the general location of the ACF river basin, Figure 2 the major features of the Apalachicola River basin, and Figure 3 the major features of the Apalachicola Bay estuary. The scientific names of species listed in this report may be found in Appendix 1.

A. Physiography

The Apalachicola Bay system is a wide, shallow estuary located along the northwest Florida gulf coast that covers an area of approximately 210 square miles behind a chain of barrier islands (Gorsline, 1963). Its primary source of freshwater is the Apalachicola River, the lower segment of the Apalachicola-Chattahoochee-Flint river system. The ACF system drains an area of 19,600 square miles of Georgia, Alabama, and Florida. The Apalachicola River portion of the system is limited to the state of Florida, with a drainage area of approximately 1,030 square miles (Elder and Mattraw, 1982). The Apalachicola River flows 107 miles to the gulf from its headwaters at Jim Woodruff Dam. At high water, the river inundates an extensive forested floodplain. A thorough discussion of the Apalachicola River ecosystem can be

Figure 1

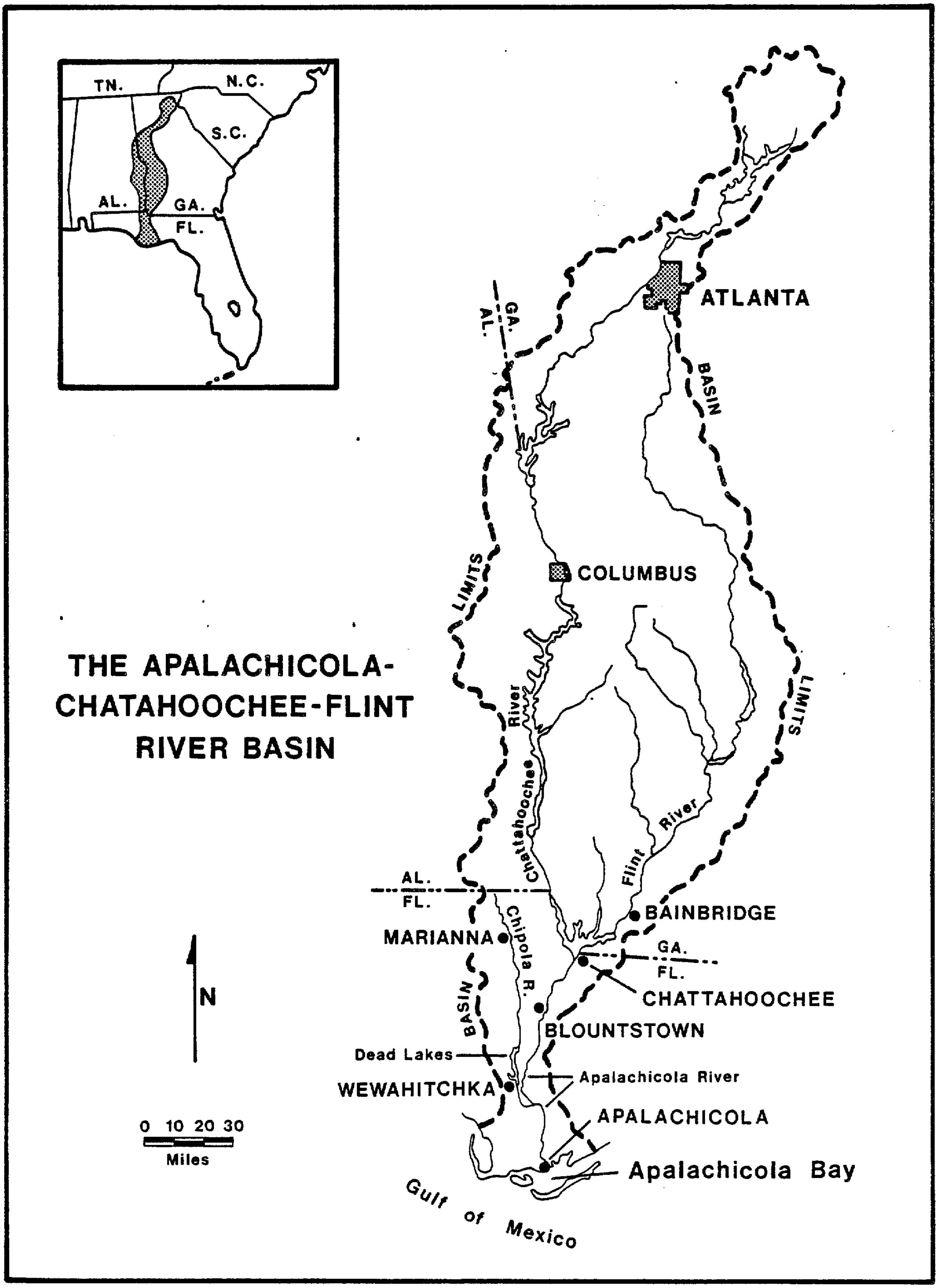

TN.
N.C.
S.C.
AL.
GA.
FL.
THE APALACHICOLA-CHATAHOOCHEE-FLINT RIVER BASIN
ATLANTA
GA.
AL.
BASIN
LIMITS
COLUMBUS
LIMITS
Chattahoochee River
Flint River
AL.
FL.
BAINBRIDGE
MARIANNA
Chipola R.
GA.
FL.
N
CHATTAHOOCHEE
BASIN
BLOUNTSTOWN
Dead Lakes
Apalachicola River
WEWAHITCHKA
0 10 20 30
Miles
APALACHICOLA
Apalachicola Bay
Gulf of Mexico

Figure 2

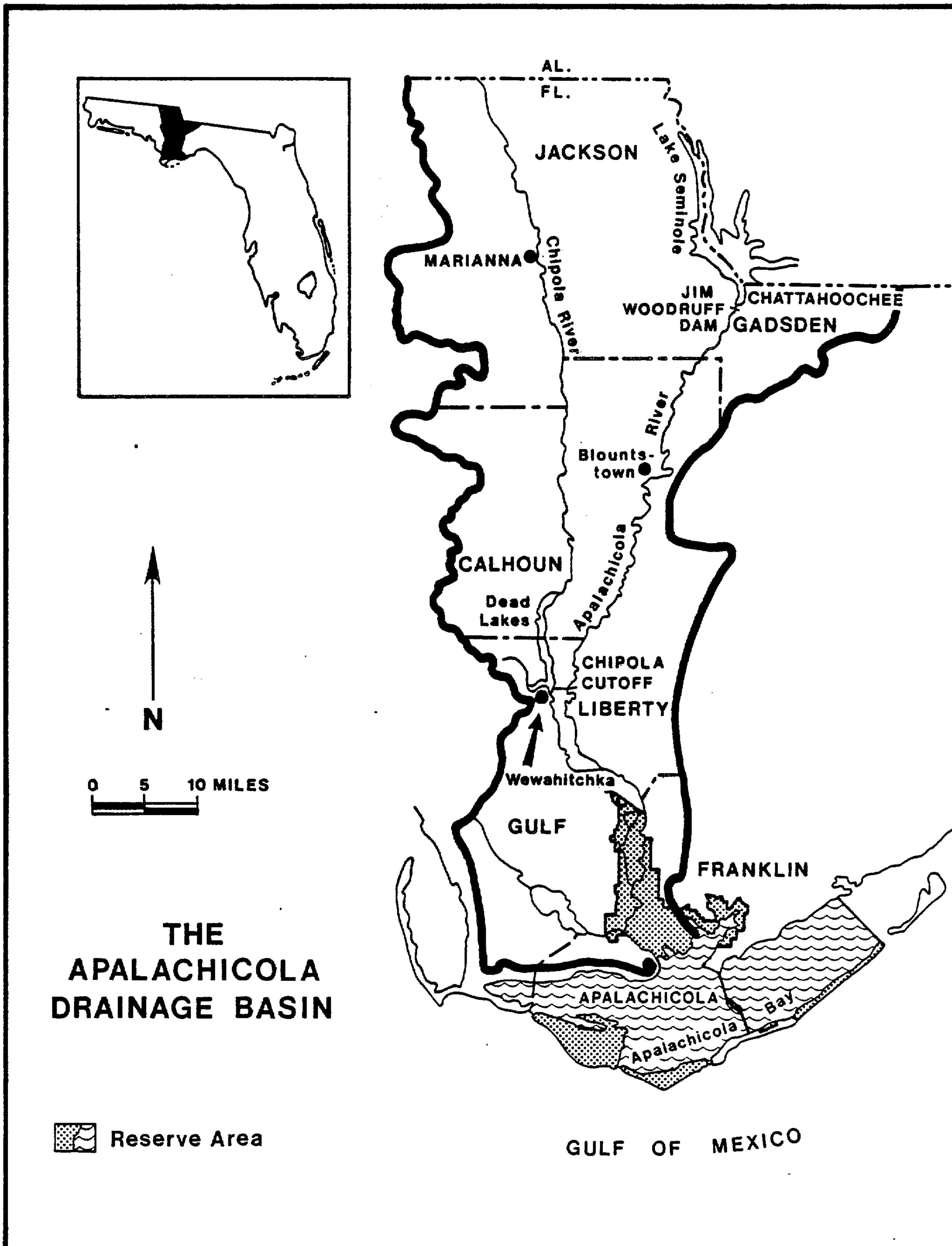
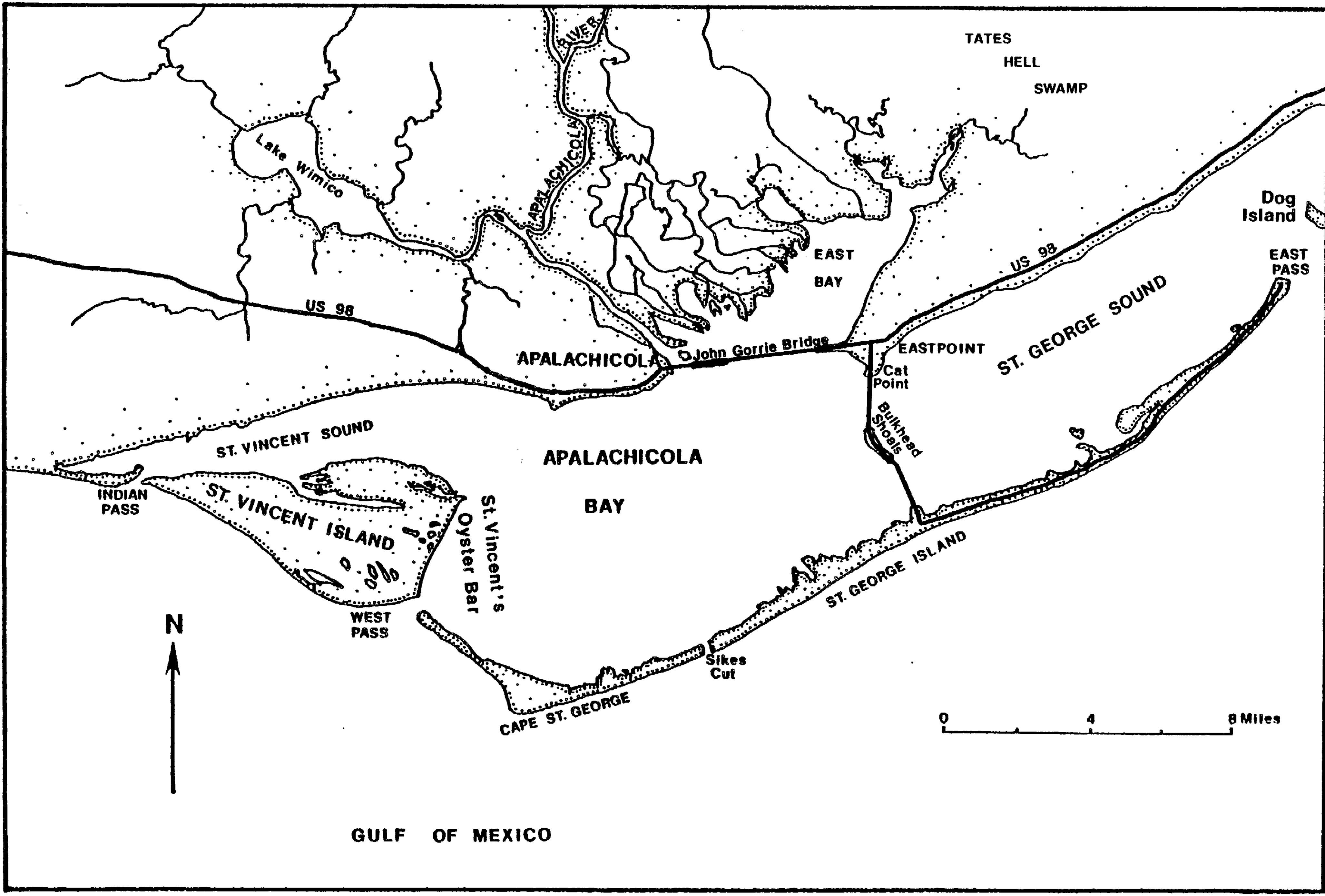

AL.
FL.
JACKSON
Lake Seminole
MARIANNA
Chipola River
JIM
WOODRUFF
DAM
CHATTAHOOCHEE
GADSDEN
River
Blounts-
town
Apalachicola
CALHOUN
Dead
Lakes
CHIPOLA
CUTOFF
LIBERTY
N
0
5
10 MILES
Wewahitchka
GULF
FRANKLIN
THE
APALACHICOLA
DRAINAGE BASIN
APALACHICOLA
Apalachicola
Bay
Reserve Area
GULF OF MEXICO

Figure 3

MAJOR FEATURES OF THE APALACHICOLA ESTUARY



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found in FDER (1984).

The Apalachicola Bay system is bounded on the gulf side by three barrier islands: St. Vincent Island, St. George Island, and Dog Island. St. Vincent is a triangular-shaped island approximately 9 miles long and up to 4 1/2 miles wide. Dog Island and St. George Island range from 0.1 to 1.0 miles wide and are 7 and 30 miles long respectively. They are both covered by low sand dunes, and to a lesser extent by marshes. St. Vincent Island, on the other hand, contains large tracts of fresh and salt water marshes.

Between the islands are inlets and passes to the Gulf of Mexico. The bay system may be divided into four sections based on both natural bathymetry and man-made structural alterations. They are East Bay, St. Vincent Sound, Apalachicola Bay, and St. George Sound (Figure 3). East Bay, north and east of the Apalachicola River delta, is surrounded by extensive marshes and swamps, and has a average depth of 3 feet (Dawson, 1955). The bay receives freshwater from the numerous distributaries of the Apalachicola River and Tate's Hell Swamp. The John Gorrie Memorial Bridge is considered its southern limit. A causeway extending west from Eastpoint, and a causeway island near the river mouth form partial barriers between East Bay and Apalachicola Bay.

To the west is St. Vincent Sound, which is also shallow, with an average depth of 4 feet, and contains numerous oyster bars and lumps (Gorsline, 1963). It separates St. Vincent Island from the mainland and is linked to the gulf by Indian Pass. Maximum water depth in Indian Pass is 12 feet near its entrance.

Apalachicola Bay is the central and widest portion of the estuary. It is separated from St. Vincent Sound by shoal areas and oyster bars. To the north it is separated from the river mouth, delta, and East Bay by the John Gorrie Memorial Bridge. The western and southern land boundaries of Apalachicola Bay are St. Vincent Island and St. George Island. The bay is connected to the Gulf of Mexico through West Pass, a deep tidal inlet, and Sikes Cut, a man-made navigational channel which cuts through St. George Island and divides it into Cape St. George or Little St. George Island to the west, and St. George Island to the east. Depths in Apalachicola Bay average 6 to 9 feet at mean low water. The bay floor slopes toward the barrier islands where depths increase to 10 to 12 feet (Gorsline, 1963). Oyster lumps are scattered throughout the central bay area and near the Gorrie Bridge. There is a major submerged oyster reef, St. Vincent Bar or Dry Bar, which extends in a north-south direction from St. Vincent Island's eastern edge towards Cape St. George. To the east Apalachicola Bay is bounded by Bulkhead Shoal, a natural submerged bar that extends from Cat Point on the mainland to East Hole on St. George Island. Construction of a causeway island in the center of the bar and a causeway extension at St. George Island raised two portions of this barrier above water level.

St. George Sound extends from Bulkhead Shoal to the Carrabelle River and East Pass. Numerous oyster bars, lumps, shoal areas, and channels fill St. George Sound. Its average depth is about nine feet and, like Apalachicola Bay, it gets deeper toward the barrier islands with a maximum depth of 20 feet.

East Pass, a broad opening between St. George Island and Dog Island, has an average depth of 14 feet and connects St. George Sound with the Gulf of Mexico (Gorsline, 1963). Dog Island Sound and Alligator Harbor are included in the geographical boundaries of the estuary, yet are influenced minimally by the Apalachicola River due to distance, current direction, and submerged shoals.

Several navigation projects in the Apalachicola estuary have resulted in alterations to the natural environment, apart from the previously mentioned bridges, causeways, and Sikes Cut. These include the Gulf Intracoastal Waterway Channel, the Two Mile Breakwater and Extension Channel, the Eastpoint Breakwater and Channel, and the Scipio Creek Boat Basin and Channel. These projects and their dimensions are described in Chapter IV of this report. All these alterations contribute to the present configuration of the Apalachicola Bay system. Their effects on bathymetry have primarily been increasing depth in areas of channels, decreasing depth in areas of open-water spoil placement, and removal of bay bottom area with creation of the Two Mile and Eastpoint Breakwaters and spoil islands. Other man-made changes in bay topography include the creation of oyster reefs by the planting of cultch in many areas of the bay.

B. Geology and Sediments

The Apalachicola estuary lies along the coastal margin of the Gulf Coastal Plain. The coastal plain is the product of a major sedimentation period along the margins of the gulf, which was probably initiated in late Mesozoic time (roughly one hundred million years ago) (Gorsline, 1963). The Gulf Coastal Plain lowlands are characterized by marine sands of Pliocene age to the north and Pleistocene age nearer to the river mouth (Alt and Brooks, 1965). The large cusp of the entire Apalachicola coast is believed to have been built out by the Apalachicola River during the late Tertiary and Quaternary time and has subsequently been modified by waves and longshore drift (Kofoed, 1961). East Bay is believed to have been created by the Holocene flooding of the ancient river channel (Isphording, 1985). Features of ancestral delta systems exist from Panama City eastward to the Ochlockonee River and inland nearly 30 miles (Kofoed and Gorsline, 1963).

Based on the findings of Goldstein (1942), Van Andel and Poole (1960), Hsu (1960) and Griffen (1962); Schade (1985) concluded that the Apalachicola River is the major source of terrigenous sediments for at least 180 miles in any direction and therefore, most sands on the shelf were delivered by the river. Delivery occurred during the Pleistocene glacial period when sea-level was much lower. The Apalachicola Bay system is considered to be less than 10,000 years old with the general outline of the bay stable over the last 5,000 years, except for the migration of the delta front southward into the estuary (Tanner, 1983). Based on digitization of bathymetric charts for the period 1896-1982, the average progradation was found to be 3.0 feet/year, with estuarine surface area decreasing about 5% during this period (Donoghue, personal communication).

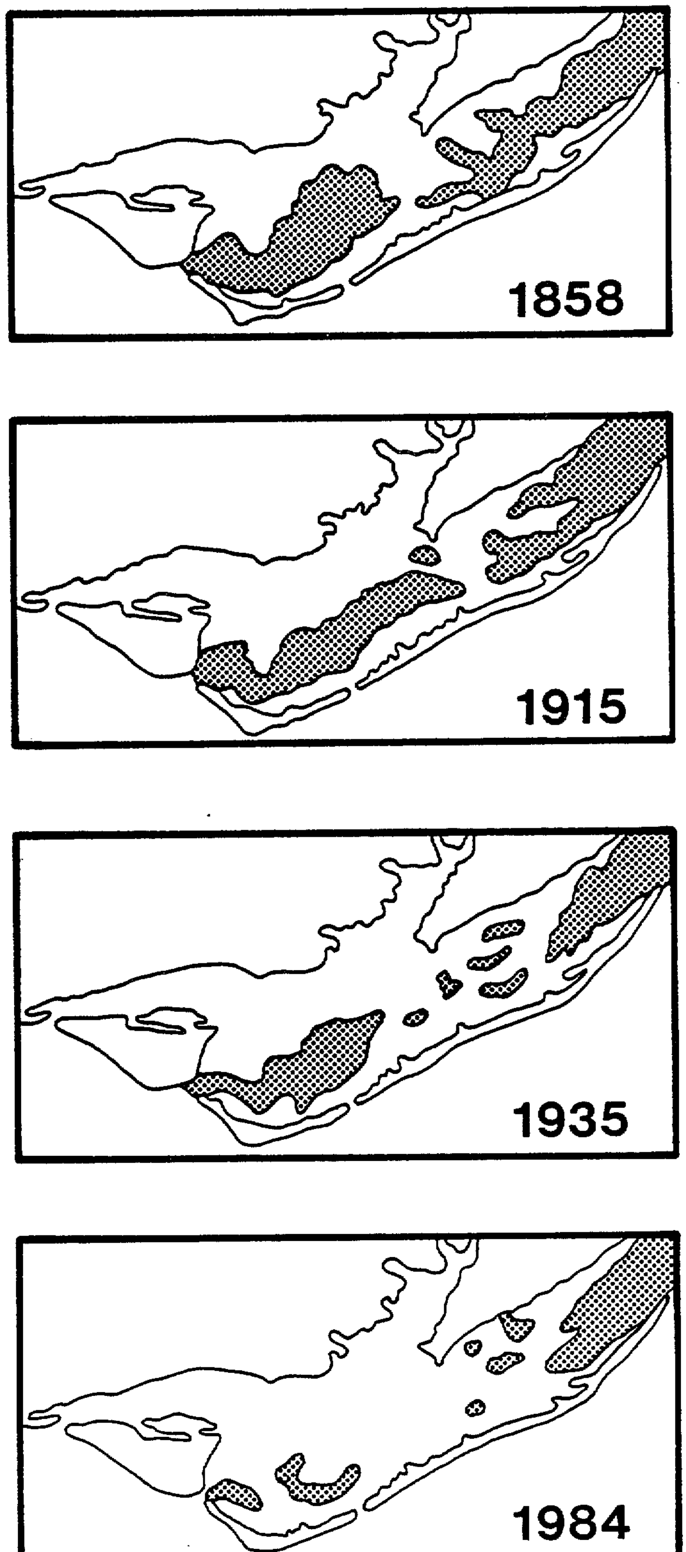
Sea level 16,000 to 20,000 years ago is believed to have been 250 to 400 feet below its present level (Schade, 1985). No conclusive evidence exists for a stand of the sea higher than its present level during Recent time. The most commonly accepted theory of sea level rise has sea level rising asymptotically with the sea level 4,500 years ago being 2.0 to 4.0 meters below its current level, one meter below its current level 3,500 years ago and 0.3 to 0.7 meters 2,500 years ago (Schade, 1985). However, Stapor and Tanner (1977) derived an alternative theory contending that sea level was 0.5 to 1.5 meters below its current level 3,000 to 5,000 years ago, at its present level 2,100 to 3,000 years ago and one to two meters below its current level 1,500 to 2,100 years ago. Schade (1985) found that this alternative theory fits well with the geological evidence on St. George Island.

The development and evolution of barrier islands is an attempt by the physical environment to achieve a dynamic equilibrium wilth the hydraulic regime. Barrier islands are ephemeral features which are a response to the post-glacial submergence of the continental shelf. Stapor (1973) concluded that St. Vincent Island was formed by a successive accretion of beach ridges which was initiated at least 3,500 years ago. This makes St. Vincent the oldest of the barrier islands off the Apalachicola cost. Schade (1985) concluded that St. George Island is a relatively young island (less than 3,000 years) that is a composite of two smaller island cores grown together, plus Gap Island upon which it has welded itself. Gap Island represents the first emergent feature with a history of seaward progradation and dates back about 3,500 years. Schade (1985) hypothesizes that during the sea level decline believed to have occured 1,500 to 2,100 years ago, two other island cores emerged between Gap Island and St. Vincent Island. These two island cores are believed to have grown laterally mostly by spit progradation and eventually closed the inlet between them less than 1,000 years ago, forming a single island.

On geological time scales estuaries are ephemeral features having lifespans which measure from a few thousand years to a few tens of thousands of years (Schubel and Hirschberg, 1978). Over time, the principal factor which leads to an estuary's demise is usually by in-filling by river-born sediment load (Isphording, 1985). In-filling rates greater than 10 mm/year have been measured in the delta (Donoghue, personal communication), and Isphording (1985) calculated an average rate of 5.44 mm/year for the entire estuary, 2.87 mm/year for Apalachicola Bay, 17.2 mm/year for St. George Sound, 1.31 mm/year for East Bay, and 0.37 mm/year for St. Vincent Sound. These rates are large when compared with other gulf and Atlantic estuaries, and consequently Isphording (1985) concluded that the combination of high rates of deposition and the absence of any appreciable subsidence in the estuary will inevitably lead to its demise. Bathymetric changes in the estuary are not only important from a long-term physical perspective. Changes in bathymetry induce changes in other parameters such as salinity, water temperature, and dissolved oxygen and thereby influence the overall ecology of the system. Figure 4 outlines the reduction of depths in Apalachicola Bay

Figure 4

Depth Changes in Apalachicola Bay from 1858 to 1985



Note: Shaded areas represent depths greater than nine feet.

Source: Isphording, 1985

since 1858.

In addition to the long-term effects of in-filling, bathymetry can also be affected rapidly by hurricanes (Isphording, 1985). Substantial quantities of material can move into the estuary from increased river load and discharge, and from the barrier island sands carried by tidal surge. Conversly, sediments suspended in the water column by storm induced wave action and increased currents can be transported out of the passes into the gulf. Hurricanes can also influence the morphology and the very existence of inlets and passes. From the combination of these actions, hurricanes can effect bathymetry of the estuary, and thereby its longevity, and also can alter the sediment composition and distubution.

Since 1837, at least 35 hurricanes have passed within 150 miles of Apalachicola Bay and 16 within 50 miles. In 1985 the estuary was impacted by three seperate hurricanes; Elena, Juan, and Kate. Hurricane Elena passed within 50 miles of the estuary twice within a two-day period, and Hurricane Kate made landfall at Cape San Blas just west of the estuary, subjecting the bay to the storm's strongest quadrant. The impact of these storms on the bathymetry of the estuary is not known at this time. Isphording (1985) contains a summary of the hurricanes which have approached northwest Florida since 1837 and how they affected Apalachicola Bay.

In general, the sedimentary floor of the bay system is formed by quartz sand with a thin cover of clay in the central basin. The sediment cover in the central bay measures 30 to 60 feet thick

(Gorsline, 1963). The original source of sand which comprises the estuarine bottoms, barrier islands, and offshore sandy shelf is the Appalachian Piedmont to the north (Schnable, 1966). However, Kwon (1969) notes that most of the barrier sands found in the petrological study by Hsu (1960) are more similar to the sand of the Pleistocene delta in grain size and mineralogy than to riverine sediments. Kwon therefore concluded that beach sands were derived by reworking of Pleistocene material rather than by material from the Apalachicola River. These relict sands were probably orginally brought down the Apalachicola River from the upper reaches of the drainage basin in earlier periods when the flow of the river was greater. The lenses of sand in the bay also may have been derived in part by wave erosion of older deltaic deposits. Oyster reefs have contributed substantial calcareous debris to estuarine sediments. Kofoed (1961) and Stapor (1973) have concluded that at this time no significant amount of quartz sand material is being supplied by the river system. Most of the sand-sized sediment load of the Apalachicola River is currently being deposited at the delta front and in the distributary channels. Isphording (1985) estimated that sand represents only about one percent of the river borne sediment load deposited in the bay from the river. Much of the detrital load is therefore dissolved material, silts, and clays (Gorsline, 1963).

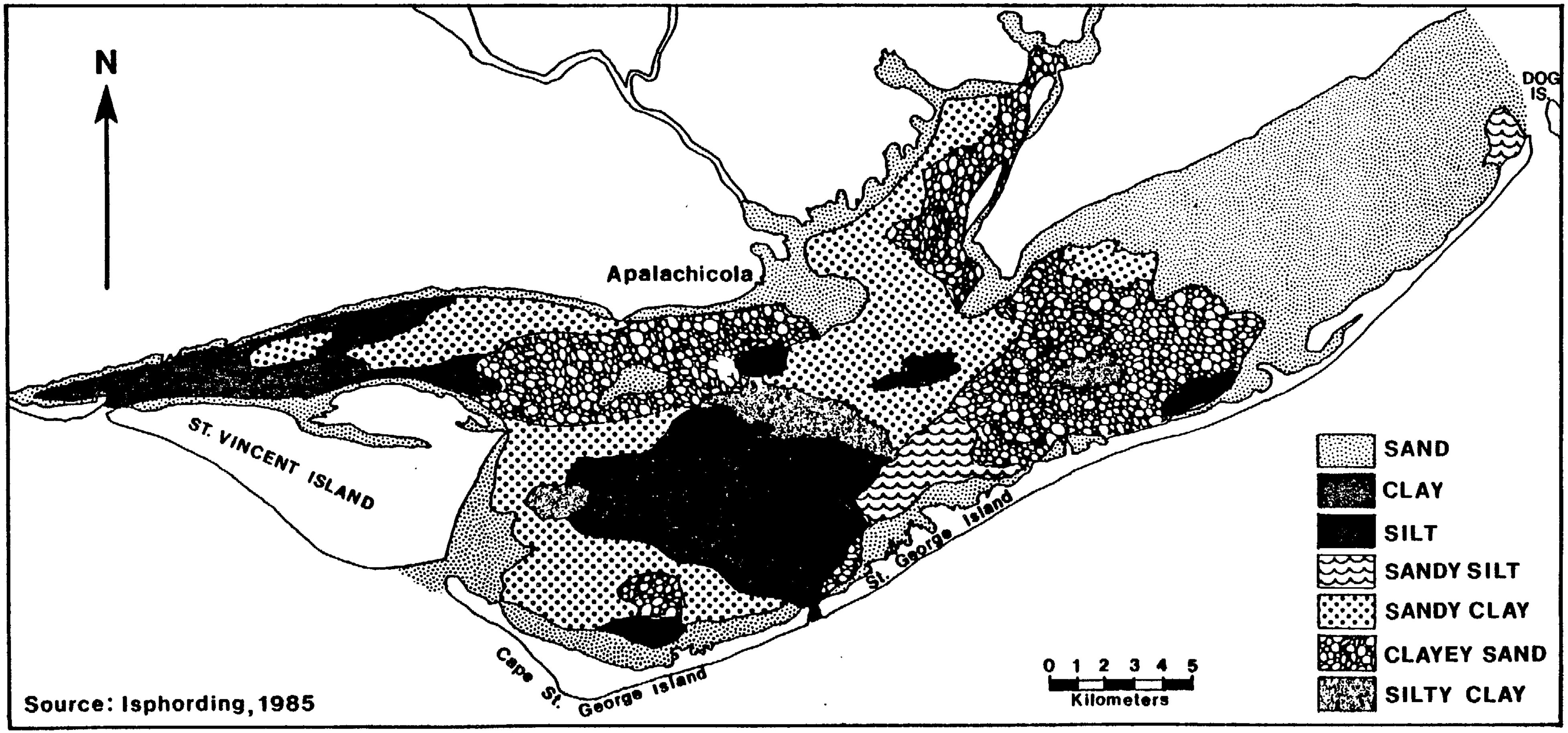
Kofoed and Gorsline (1963) concluded that the sedimentary characteristics of the Apalachicola Bay system are the result of several integrated factors including: 1) bathymetry, 2) reworking of sediments by wind, wave, and current action, 3) the production of organic materials by local faunal assemblages, and 4) sediment from the Apalachicola River. Of these, Kofoed and Gorsline (1963) considered bathymetry to be the most important single factor controlling the distribution and textural properties of bottom material. Waves and currents within the bay are also important in keeping material in suspension until it eventually reaches areas where energy is low enough to permit deposition.

The bottom sediment types in Apalachicola Bay are shown in Figure 5. St. George Sound is shown to be predominantly sandy, whereas the rest of the bay sediments have varying degrees of clay mixed with the sand. Isphording (1985) compared the bottom sediment characteristics in the bay at present to those in 1825 by dating core samples. There was little difference in St. George Sound sediments; however, in the rest of the bay, there was a considerable shift from silts to clays. Clays, sandy clays, and clayey sands which are so widespread on the present map were formerly silty clays, silty sands, and sand-silt-clay mixtures. Isphording (1985) hypothesized that the present scarcity of silt in the Apalachicola Bay sediments is due to either: 1) a change in the sediment carried by the Apalachicola River due to the upstream reservoirs, 2) events taking place in the bay which have acted to remove or bury silt, or 3) a combination of both.

FDER (1984) concluded that the quantity of maintenance dredging on the Apalachicola River has been increasing over time, and that the areas requiring dredging are moving progressively downstream. There is concern about whether maintenance dredging

Figure 5

BOTTOM SEDIMENT TYPES OF APALACHICOLA BAY



on the Apalachicola River is causing higher in-filling rates in the bay. However, since the sites where major dredging increases are occurring are over 35 miles upriver from the bay, it is unlikely that in-filling rates are affected appreciably by dredging in the river.

Biological assemblages in Apalachicola Bay contribute varying amounts of organic material and calcareous debris to the sediment. Once in the sediment, organic material becomes food for burrowing organisms and is acted upon by bacteria and returned to the water column as inorganic nutrients (Emery and Ritterberg, 1952). Kofoed and Gorsline (1963) found that a correlation exists between bathymetry and organic content of sediments. Organic carbon values were found to be low in elevated areas where organic material is easily resuspended from the sediment by current action. In depressions, the organic carbon content tends to increase. Organic carbon and nitrogen are deposited under the same energy conditions favorable to clay deposition and the percent composition is thus higher in the finer sediments. In contrast, Isphording (1985) noted a low correlation between organic carbon concentration and depth which he attributed to the dynamic conditions which exist in the bay. Isphording (1985) also found calcareous debris derived from shell material to be widespread throughout the bay and noted a low correlation between carbonate carbon content and depth, again due to the dynamic conditions in the bay.

Kofoed (1961) and Schnable (1966) concluded that no detrital material from the Apalachicola River has been deposited east of

Cat Point since sea level reached its current level. The material from the river which is not deposited in the bay is channeled to the open gulf by way of West Pass and Indian Pass (Kofoed and Gorsline, 1963). These inlets are oriented so that the water currents and sediments are directed offshore.

Heavy minerals are uniformly distributed over the bay, rarely exceeding one percent of the sediment by weight. Glauconite is common in the small pellets and cavity fillings of silt and clay-size material found throughout the bay. It is believed that these grains originated within the bay (Barackman, 1964). Kofoed and Gorsline, (1963) found kaolinite to be the most abundant clay-mineral in the bay, but Isphording (1985) found montmorillonite to be the most abundant clay mineral. Other clay-minerals in the bay noted by Isphording (1985) include kaolinite, palygorskite (attapulgite), and illite.

Since dredging of the bay's navigation channels is the major focus of this document, Table 1 summarizes the sediment grain-size distribution in the navigation channels, and Figure 6 indicates where each sample was taken. The table shows that sediments in the channel bottoms tend to be composed of mostly silts, clays, and colloids on the GIWW, except at Stations 1 and 7 where the material is composed of medium to fine-grained sand. At Two Mile, Eastpoint and Scipio Creek the material is mostly fine sand and silt. In Sikes Cut the material is medium to fine-grained sand (COE, 1981, 1982). If the grain-size distribution for the Eastpoint Channel reported in COE (1982) is compared with data for similar sites in Geoscience (1984), it is found that the later

TABLE 1

SEDIMENT GRAIN-SIZE DISTRIBUTION
IN APALACHICOLA BAY NAVIGATION CHANNELS

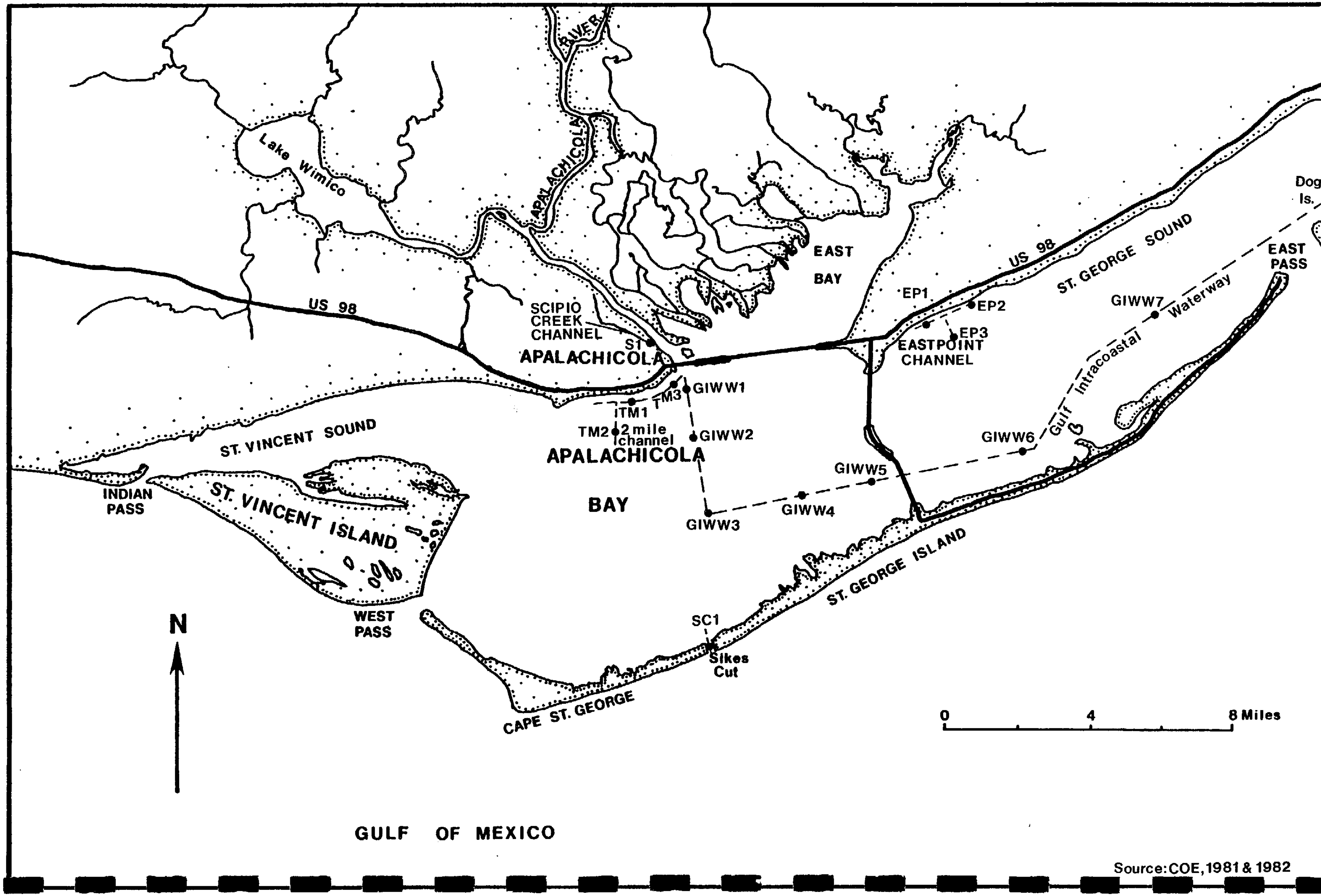
	% Coarse Sand (1), (2) x>2.0 (4)	% Medium Sand 2.0>x>.425	% Fine Sand .425>x>.074	% Silt .074>x>.005	% Clay .005>x>.001	% Colloids .001>x
GIWW(3)						
1	<1%	83%	14%	2%	<1%	<1%
2	<1%	<1%	4%	35%	16%	44%
3	<1%	<1%	2%	32%	16%	50%
4	<1%	<1%	6%	34%	13%	47%
5	<1%	<1%	5%	36%	12%	46%
6	<1%	1%	16%	27%	14%	41%
7	2%	29%	55%	8%	<1%	6%
Two Mile						
1	<1%	2%	48%	35%	5%	10%
2	<1%	<1%	60%	22%	10%	8%
3	<1%	5%	90%	3%	<1%	2%
Eastpoint						
1	<1%	1%	56%	30%	10%	3%
2	<1%	<1%	57%	38%	2%	3%
3	<1%	15%	37%	38%	5%	5%
Sikes Cut						
	<1%	10%	90%	<1%	<1%	<1%
Scipio Creek						
	<1%	<1%	50%	40%	7%	3%

Sources: COE (1981), COE (1982)

1. X is the grain diameter
2. size terms given in the column are non-standard.
3. Data for GIWW sites collected in 1975.
4. grain-size listed in mm.

Figure 6

SEDIMENT SAMPLES FROM THE APALACHICOLA BAY NAVIGATION CHANNELS



data set indicates that Eastpoint contains substantially more fine-sized particles. For instance Geoscience (1984) found colloids (<0.001 mm) to account for 26% and 44% of the sediments in the west and east legs of the channel, respectively; whereas COE (1982) found only 3% in both legs to be in this classification. These data suggest that the channels are accumulating finer material over time.

C. Hydrology and Climate

The Apalachicola basin is located in a transitional climatic zone between the semitropical climate of peninsular Florida and the subtropical temperate climate of the southeastern United States.

Average annual rainfall in the Apalachicola River basin in Florida is about 58 inches. Mean annual potential evapotranspiration is between 37 and 43 inches. Average annual rainfall in the Chattahoochee and Flint basins varies from 47 inches to above 60 inches. In the northern portion of the basin, average rainfall is highest. Average rainfall then decreases steadily to below 50 inches/year in southern Georgia, and then increases to approximately 60 inches/year in the coastal region (Alabama, et al., 1984). Rainfall in the Chattahoochee-Flint basin is slightly higher in the winter, but much lower in the summer than Florida rainfall. Similar amounts fall in the spring and the least rainfall is in October and November (Leitman, et al., 1983). The A-C-F basin in general exhibits rainfall peaks in early spring and except in the immediate receiving areas (Conner, et al., 1982). Net movement of water is from east to west. The more saline gulf water enters through St. George Sound and moves west, mixing with the fresher water in East Bay and Apalachicola Bay, and eventually back out to the gulf through Sikes Cut, West Pass, and Indian Pass (Ingle and Dawson, 1953; Conner, et al., 1982). Although the western passes account for only ten percent of the inlet area in the bay, they serve as outlets for about two-thirds of the total bay discharge (Gorsline, 1963).

Apalachicola Bay is in an area of transition between the semi-diurnal tides of southwestern Florida and the diurnal tides of northwestern Florida, and its tides are therefore classified as mixed. High tide arrives progressively later to the western and mainland parts of the bay; high water reaches West Pass two hours after East Pass, and high tide arrives in Apalachicola one half hour after West Pass. The normal tidal range in the bay is one to two feet, with a maximum range of three feet (Dawson, 1955; Gorsline, 1963).

The predominant annual surface wind speeds and directions are summarized in Table 2. This table indicates a large variability in wind direction over the course of the year. Cold, dry fronts from Canada cause winds to tend to come from a north to north-easterly direction during the fall and winter. In contrast, warm, moist flow from the Gulf of Mexico tends to dominate the weather pattern in the spring and summer, and therfore winds tend to be from a southerly direction. Strong winds can modify water movement to the point of obscuring tidal effects. When strong north

TABLE 2

Predominant Annual Surface Wind Speed and Direction (1)

Predominant Direction	Percent of Time	Mean Speed (Knots)
N	8.4	7.4
NNE	4.3	6.8
NE	7.8	6.8
ENE	5.5	6.4
E	7.3	7.1
ESE	4.9	8.2
SE	8.4	8.3
SSE	5.4	8.0
S	7.9	6.9
SSW	3.6	6.5
SW	5.2	6.4
WSW	2.9	6.2
W	5.4	6.1
WNW	3.6	6.6
NW	5.2	7.2
NNW	3.1	8.0
CALM	11.2	

Source: Isphording (1985)

1. Period of record, 1948-1949,1975-1982. Data collected at the National Weather Service Station, Apalachicola, Florida.

north and northeasterly winds blow across Apalachicola Bay, the net effect is a deflection of water to the west and south with greater flows through Indian Pass and West Pass. In the bay, water velocities rarely exceed 1.5 feet per second, but in the passes, velocities of 10 feet per second are common (Gorsline, 1963). Strong winds may thoroughly mix the shallow water of the bay, but winds of lesser velocity affect only the surface layer, resulting in stratification of the water column (Estabrook, 1973).

Several efforts have been made to model the circulation patterns of Apalachicola Bay. Vansant (1980) developed a two-dimensional numerical model to study the tidal currents in Apalachicola Bay. The results indicated that water exchange between the bay and open gulf occurs predomnantly through West Pass. However, Vansant (1980) assumed that the influence of Sikes Cut was negligible and therefore did not include the cut in the model.

The University of Florida Department of Civil Engineering deveolped a real-time, two-dimensional, vertically averaged, finite-element CAFE-1 model to simulate the circulation in Apalachicola Bay and St. George Sound (Graham, et al., 1979; Conner, et al., 1982). This model was developed to study hydrodynamics and pollutant migration in the Apalachicola Bay system. The model was intended to determine water velocity and direction, water quality in the bay as it corresponds to water quality in the river, and the salinity of bay waters (Conner, et al., 1982). The model was developed using the extensive ecological data base developed by Dr. R.J. Livingston at Florida State University. After its development, this model was modified to enable it to predict changes in currents due to alterations of topography such as the creation of causeways or spoil islands and dredged material disposal sites (Graham, et al., 1979). In a simulation of the bay with and without the causeway islands of Patton Bridge, Graham, et al. (1979) found that spoil islands and causeways can significantly affect tidal circulation.

In conjunction with permitting conditions imposed by DER, the COE contracted to have a numerical model developed to simulate the hydrodynamic and salinity regimes in Apalachicola Bay and adjacent waters of St. George Sound, East Bay, and St. Vincent Sound. The model utilized was a modification of an existing two-dimensional, vertically averaged, finite difference model. Additional boundary conditions, constituent advection and diffusion, and reaction dynamics were added to the model along with a variable grid capability for greater resolution of critical hydrodynamic features. The model provides a pseudo-three-dimensional effect since its equations are forced to satisfy boundary conditions at the bottom and surface of the water column (Raney and Youngblood, 1983). This model represents an improvement over the University of Florida model because it is able to incorporate wind and because the data base associated with the model was specifically designed for developing a model.

D. Physical-Chemical Properties

In this section an overview of the physical-chemical properties of the bay system will be presented. Table 3 provides surface and bottom mean values from 1972 to 1983 for selected physical and chemical parameters at several locations throughout the bay. Figure 7 shows the location of these monitoring stations.

1. Temperature

Water temperature in Apalachicola Bay closely approximates that of the air. There is little spatial variation in temperature over the bay, and vertical stratification of temperature is minimal. Temperature peaks occur in July and August, and winter lows occur in January and February. Throughout the year the temperature may range from 3.5°C to 32°C. Summer temperature peaks show little variation over time, but winter minima may vary as much as 4°C from year to year. Table 3 summarized mean surface and bottom temperatures found in Apalachicola Bay from 1972 to 1983 at selected locations.

2. Salinity

Salnity is considered to be the single most important determinant of the distribution of organisms in the estuary (Livingston, 1983). The salinity structure of the Apalachicola Bay system is primarily determined by freshwater inflow from the Apalachicola River. Since the majority of the Apalachicola-Chattahoochee-Flint River system is in Georgia and Alabama, flow levels in the Apalachicola River are more closely correlated with rainfall in Georgia and Alabama than with local rainfall.

TABLE 3

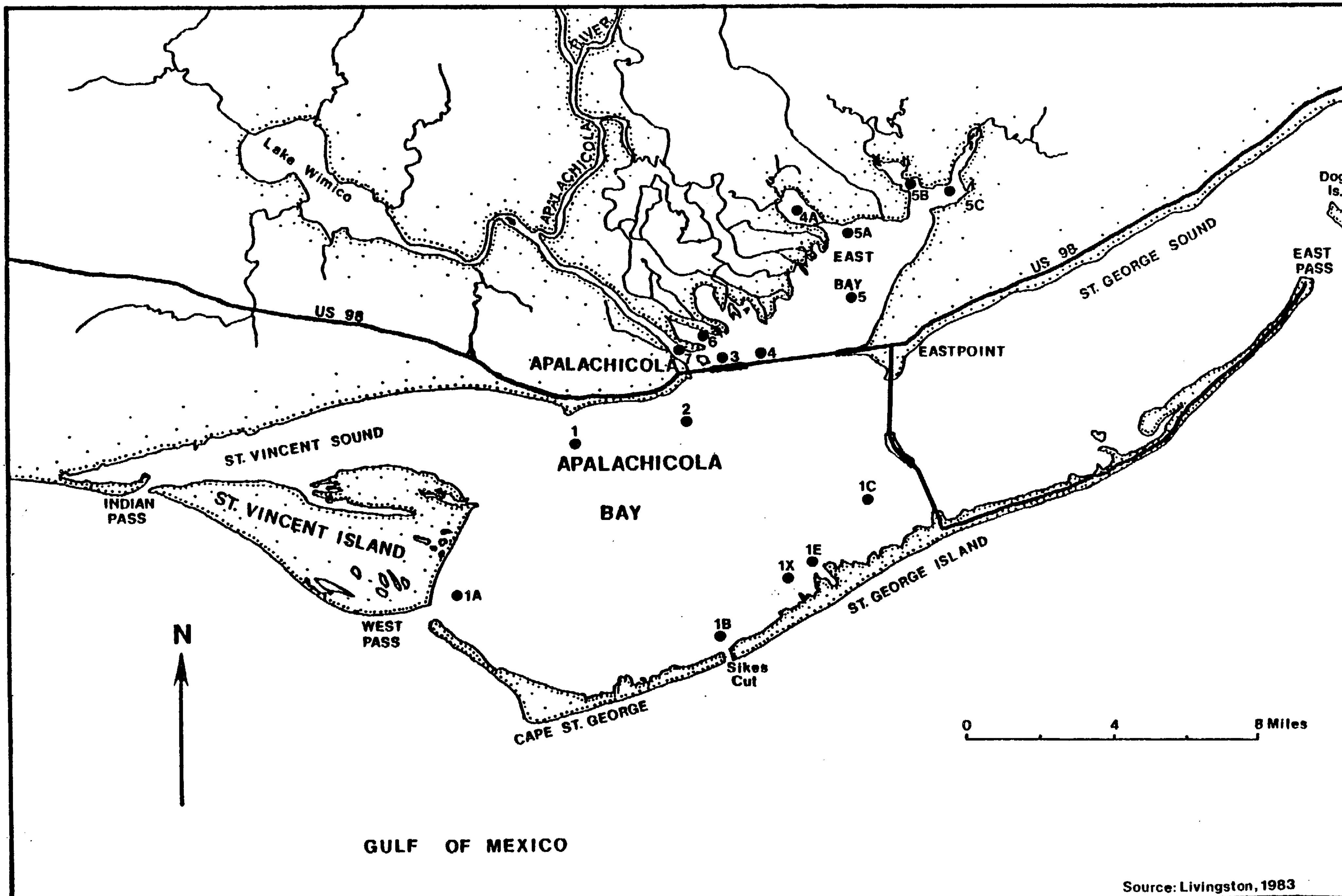
Mean Values of Selected Physical and Chemical Parameters for Apalachicola Bay at Selected Locations (1)

	DO(mg/l)	Turbidity (JTU)	Temperature (C°)	Salinity (ppt)
Station 1				
Surface	8.4	17.0	21.6	10.5
Bottom	7.8	22.3	21.5	16.2
Station 2				
Surface	7.5	18.7	21.4	2.8
Bottom	7.1	23.2	21.3	9.5
Station 3				
Surface	8.2	18.3	21.5	2.7
Bottom	8.0	22.2	21.3	4.4
Station 1A				
Surface	8.3	13.0	22.1	17.2
Bottom	8.0	21.5	21.8	21.7
Station 1B				
Surface	8.3	11.6	22.0	18.0
Bottom	7.7	16.9	21.6	25.9
Station 1C				
Surface	8.2	12.7	22.1	15.7
Bottom	7.7	15.9	21.7	20.2

Source: Livingston (computer printout of data base)
1. See Figure 5 for location of station numbers.

Figure 7

SELECTED LONG-TERM MONITORING STATIONS OF DR. R. J. LIVINGSTON'S STUDIES



Source: Livingston, 1983

Consequently, salinity in the estuary is more closely correlated with upbasin rainfall (Livingston, 1983). In the past several decades a series of reservoirs have been constructed on the ACF river system. A detailed discussion of how this system functions and the capabilities of each reservoir may be found in Alabama, et al. (1984). Because of the physiography of the basin the reservoirs have limited storage capacity and are only able to control flows over low to moderate discharges. Similarly, upstream consumption of water only becomes significant in lower flows (Alabama, et al., 1984). Since salinity in the estuary is affected by river flow, reservoir management actions and upstream consumption can affect the salinity regime in the estuary in periods of low flow.

Discharge from the river peaks in the winter and early spring months, and declines until fall when low flow occurs. Average daily flows in the river can vary ten-fold in a single year. Figure 8 shows the average monthly flow of the Apalachicola River at Chattahoochee, Florida from 1957 to 1984. Table 3 gives mean salinity values in the estuary from 1972 to 1983. Measured values ranged from 0 to 35 ppt. Figure 9 shows the average surface salinities at different areas within in the estuary, though wide variation occurs throughout the bay at any given time.

The great variations in salinity, temporally, spatially, and vertically, are closely related to annual riverflow and wind patterns. In late summer and fall, low flows and southerly winds can result in surface salinities greater than 20 ppt near the rivermouth, with correspondingly high salinities throughout the

Figure 8
AVERAGE MONTHLY FLOWS OF THE APALACHICOLA RIVER AT CHATTAHOOCHEE, 1957 TO 1984

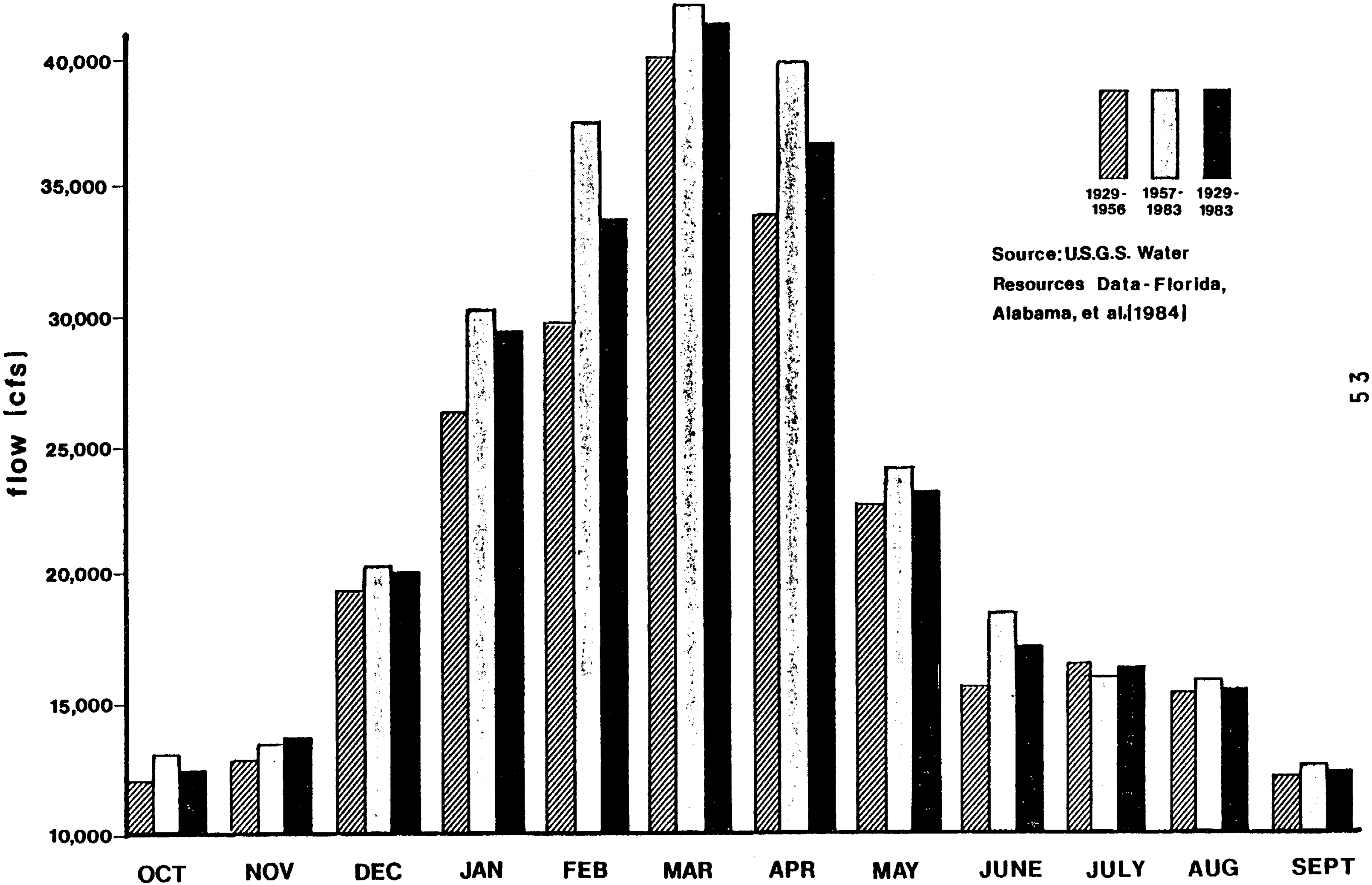
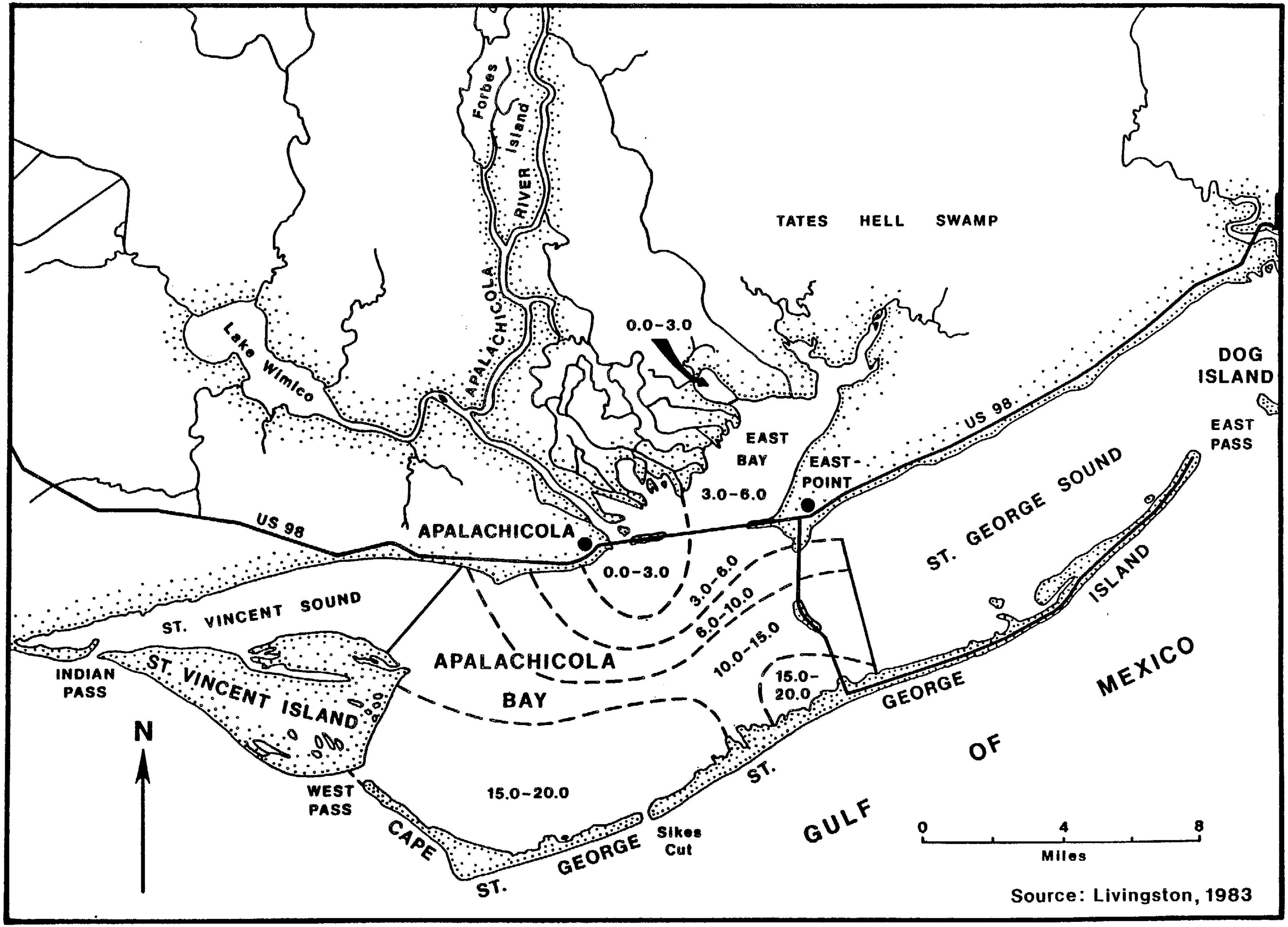


Figure 9
AVERAGE SURFACE WATER SALINITY (1972 - 1979)



bay system (Livingston, 1984). During winter and spring flooding peaks, when river discharge is high and strong northerly winds are blowing, freshwater may spread out over most of the bay surface. At these times, salinity stratification commonly occurs in much of the bay, particularly the channels and passes (Estabrook, 1973; Clarke, 1975).

Spatial salinity distribution is affected most by riverflow and, to a lesser extent, local rainfall. East Bay, Apalachicola Bay, and St. Vincent Sound show greater response to freshwater inflow than St. George Sound. The lowest recorded salinities are found near the rivermouth and in East Bay, which receives freshwater drainage from Tate's Hell Swamp (Gorsline, 1963; Livingston, 1983). When local rainfall is heavy in late summer and early fall, reduced salinities occur in East Bay and in the vicinity of Nick's Hole (a major area of freshwater runoff from St. George Island). The eastern sounds tend to be more saline than the western portions of the system because of their broad connections with the gulf and the minimal input of freshwater from runoff.

3. Color and Turbidity

Color levels in Apalachicola Bay vary seasonally and are directly related to runoff and riverflow. Peaks in color levels occur in areas of high river water input and overland runoff in winter and spring. East Bay consistently has higher color levels than Apalachicola Bay due to the drainage from Tate's Hell Swamp and forestry operations (Livingston and Duncan, 1979).

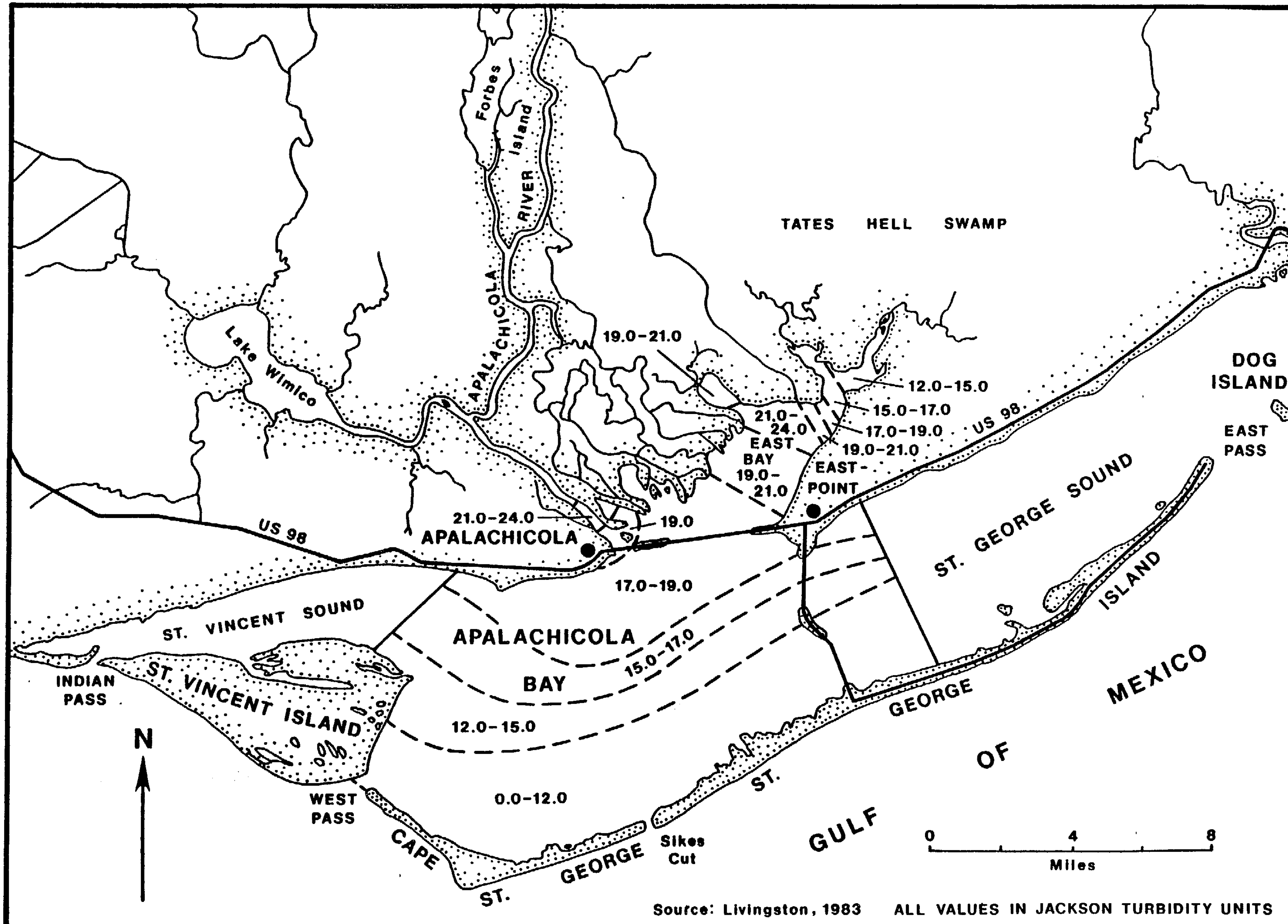
Turbidity is directly related to riverflow. Turbidity values measured in the estuary ranged from 0 to 145 JTU's (Jackson Turbidity Units) throughout most of the sampling stations. River turbidity values have been found to be highest during the months of Febuary through July when riverflow also is highest, and lowest during the late summer and fall when flow subsides. Strong winds have also been shown to increase turbidity due to resuspension of bottom sediments (Estabrook, 1973). Average surface turbidity values found throughout the bay from 1972 to 1979 are shown in Figure 10 (also see Table 3). Because of the high variability in turbidity levels, the values in Figure 10 merely diagram general trends in the system. The value at any given location at a specific point in time can vary substantially from the values on Figure 10. The same is also true for Figure 11.

4. Dissolved Oxygen

The amount of dissolved oxygen (DO) in a body of water is related to air/water mixing, biological activity, temperature, and salinity. In Apalachicola Bay, peak levels of dissolved oxygen are found in winter and spring when temperatures are lowest. Lower values are found in the warm summer and fall months (Livingston, 1983). Spacially, highest levels of dissolved oxygen are found in upper East Bay, Nick's Hole, and the eastern side of St. Vincent Island. There is considerable natural daily and seasonal fluctuation of DO levels in Apalachicola Bay. Diurnally, the lowest DO concentrations occur in the early morning. As yet there is no indication that cultural eutrophication is causing

Figure 10

AVERAGE SURFACE TURBIDITY IN APALACHICOLA BAY (1972-1979)



widespread reductions of DO in the estuary. In certain locations, such as the mouth of Scipio Creek, indications of significant reductions in DO levels have been noted (Livingston, 1983a). Table 3 gives mean DO values found at selected locations in the bay from 1972 to 1983, and Figure 11 shows the average bottom dissolved oxygen level throughout the bay from 1972 to 1979.

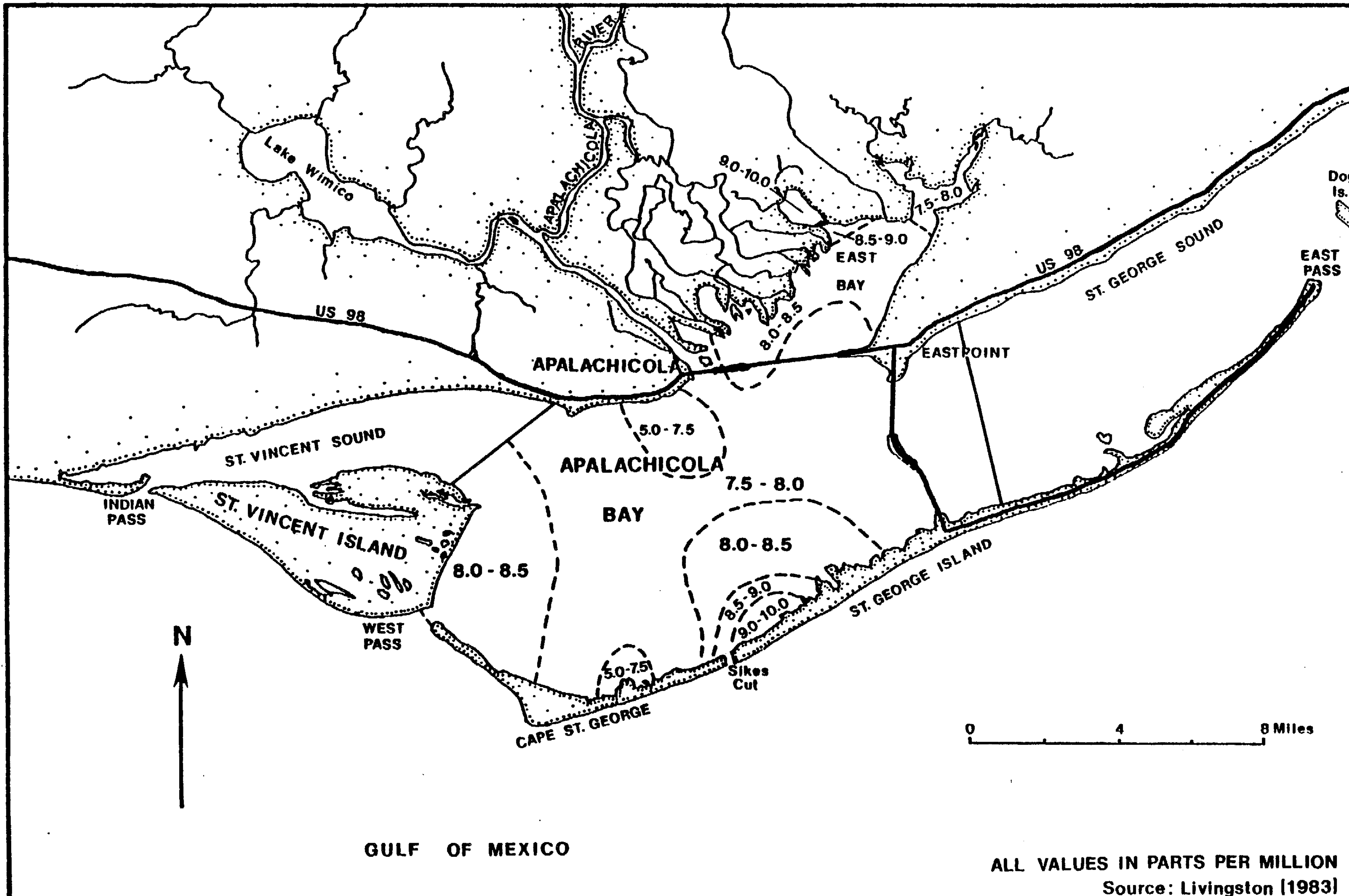
5. Nutrients

Among the major features which determine habitat characteristics of the Apalachicola Bay estuary are the flow of the Apalachicola River and its effects on nutrient transport from the river's floodplain (Livingston, 1984a). Nutrients are transported to the estuary both in the form of detritus (organic particulate matter from leaves and twigs) and as compounds dissolved in the water column. Annual flooding causes surges in nutrient transport, and these nutrients are the foundation for estuarine productivity. Nutrients transported from the Apalachicola River floodplain to its estuary are especially important since detritivores occupy key positions in the bay's food web (Livingston, 1983).

The major nutrients affecting estuarine productivity are nitrogen, phosphorus, and carbon. Nitrogen and phosphorus are the two nutrients most often in limited supply in aquatic ecosystems. Organic carbon is the principle constituent in all organic material. Phosphorus has been found to be the most critical limiting nutrient in Apalachicola Bay (Myers and Iverson, 1977). Ryan, et al. (in prep) found that the TKN:TOC ratio for Apalachi-

Figure 11

AVERAGE BOTTOM DISSOLVED OXYGEN VALUES IN APALACHICOLA BAY (1972-1979)



cola Bay was an order of magnitude lower than normal estuarine sediments indicating that sediments in the bay are depleted in nitrogen relative to carbon. In the water column, however, TKN:TOC ratios are within the expected natural range. In summation, Ryan et al. (in prep) concluded that these data suggest that nitrogen is removed from the sediments rapidly relative to TOC. Although the fate of the nitrogen is unknown, it is conceivable that TKN is remobilized from the sediments to the water column and either utilized by biota or exported from the bay.

Meeter, et al. (1979) found the cyclic productivity of the Apalachicola Bay system to depend upon both annual pulses of detritus and the periodic large scale import of detritus during years of increased flow. Annual flooding causes appreciable surges in nutrient transport, especially in particulate organic form. In an 86-day flood event in 1980, Mattraw and Elder (1984) found that about one-half of the annual outflow of organic carbon, nitrogen, and phosphorus and 60 percent of the detritus were transported past their sampling station closest to the bay. Total organic carbon concentrations at this station were 50 percent higher than those measured below Jim Woodruff Dam even though streamflow had only increased by 25 percent. These data indicate that a substantial portion of the annual organic carbon contribution to the bay comes from the Apalachicola River floodplain. Nitrogen and phosphorus increases were similar to discharge increases. The degree and timing of river flooding affects the level of detrital loading to the estuary and subsequently, the productivity of the bay system (Livingston, 1981).

As noted earlier, the reservoir system in the ACF basin is only capable of significantly modifying flows in the low to moderate discharge range. During flood stage the management capabilities of the system are quite limited because of the limited storage capacity of the upstream reservoirs. Studies by the USGS (Leitman et al, 1983) and the Northwest Florida Water Management District (Maristany, 1981) have shown that the annual discharge regime for the Apalachicola River has not been significantly modified by the upstream reservoirs. Therefore, the impacts of the reservoir system on the detrital loading of the estuary from the Apalachicola River's floodplain are believed to be minimal.

Peaks in commercial seafood catches from the bay were found to follow years of increased river discharge by Meeter, et al. (1979). It was therefore hypothesized by Wharton, et al. (1982) that increases in seafood catches result from the unusually large load of detritus carried into the bay by the river. The surplus detritus is accumulated from portions of the floodplain not normally inundated and is also picked up by the additional scouring of areas that are annually flooded.

Since Jim Woodruff Dam restricts particulate flow from the Chattahoochee and Flint Rivers, the Chipola and Apalachicola floodplains are the primary contributors of detritus to the bay. Outflow at Jim Woodruff Dam does contain a substantial nutrient load in a dissolved form (Elder and Cairns, 1982) and is the largest single contributor of nutrients to Apalachicola Bay (Mattraw & Elder, 1984). Nutrient concentrations were measured in Apalachicola Bay in 1971-1972 by Estabrook. Nitrate (3-180 ug/l) and silicate (400-2500 ug/l) values were found to vary inversely with salinity, with the greatest concentrations occuring in winter during highest river discharge. Orthophosphate concentrations ranged from 4-8 ug/l and correlated with turbidity. There were higher ammonia concentrations in the bay (7-25 ug/1) than in the river indicating a possible ammonia source within the bay (i.e., not coming from river water). Estabrook (1973) postulated that zooplankton excretion might be the source of such ammonia. Nutrients were not found to be limiting to phytoplankton growth for most of the year in Apalachicola Bay; however, during low wind conditions in late summer, phosphate may be limiting.

6. Water Quality

The lower Apalachicola River and Bay system is considered to be relatively free of pollution, although isolated areas have been identified as having pollution problems. Low dissolved oxygen concentrations (<4 mg/l) have been measured in Scipio Creek, Eagle Creek, and the St. George Island Boat Basin. These water bodies receive stormwater runoff from municipal, urban, and developing areas. High fecal coliform bacterial levels have been noted in Scipio Creek, East Bay, Eagle Creek, and the Apalachicola Boat Basin. Sources of fecal coliform include municipal drainages, and agricultural and stormwater runoff (Livingston,1983a). The Apalachicola Bay Protection Act of 1984 provided funds to upgrade the municipal sewage plants in Apalachicola, Eastpoint, and Carrabelle. The water quality in the upper Apalachicola River basin is good, although problems have been identified at some locations. FDER (1984) contains a summary of the water quality in the Apalachicola River, and Jackman and Hand (1982, 1984) can be referred to for a comprehensive summary of water quality data.

7. Sediment Quality

The estuarine water column is an important transition zone in the geochemical cycle becuse of increases in pH and ionic strength associated with the change from fresh water to sea water. These increases change the solubility of substances and may also enhance flocculation and precipitation of materials. Many substances may be removed from the estuarine water column to the sediments when the waters are mixed. For example, toxic organics such as petroleum hydrocarbons (e.g. PCB's and pesticides) have low solubilities and accumulate in sediments shortly after being introduced to estuarine waters. Therefore, estuarine sediments act as a sink for some constituents, so that the pollution climate of an estuary is reflected better in the sediments than in the water column (Ryan, et al., 1984). The historic emphasis of environmental quality assessment has been through water column sampling. In estuaries water quality data can provide an understanding of the impacts of individual pollution events, but are of little value in understanding long-term trends, assessing ambient background conditions, or assessing the degree of environmental stress.

Sediment grain-size is an important qualitative predictor of sediment chemistry (Ryan, et al., 1984). Fine-grained sediments usually contain elevated concentrations of metals and hydrocarbons, while lower levels are observed in coarse-grained sediments. Fine-grained sediments have greater concentrations because they are more enriched in organic and clay materials and because they have greater surface areas which provide more binding sites.

Livingston (1983a) analyzed sediment samples taken from stations distributed throughout the bay. His results indicated that, overall, the Apalachicola Bay system remains relatively pollution-free at this time. However, the data show that some nearshore areas are being contaminated. Livingston (1983a) found a strong positive correlation between silt/clay fractions and levels of organic matter in the sediments. These same areas of high organic content also showed increased concentrations of heavy metals. Locations which showed high concentrations of metals such as chromium, copper, nickel, lead, and zinc include the following: areas which receive municipal runoff (Scipio Creek, Eagle Creek, nearshore Eastpoint), marinas (Apalachicola Boat Basin, St. George Island Boat Basin), and areas receiving agricultural runoff (Clark Creek, Murphy Creek, West Bayou). The easternmost area in St. Vincent Sound also had high metals concentrations, the source of which is unknown. Livingston (1984) found that the dredged channels of the GIWW, Eastpoint, and Two Mile also concentrate contaminants such as metals as part of the fallout of silt/clay fractions. Geoscience (1984) sampled sediments from the

Apalachicola Boat Basin and Eastpoint Channel. Both sites had high heavy metal concentrations in the sediments but failed to release appreciable amounts of these metals into the receiving water through elutriation.

Ryan, et al. (in prep) found that Apalachicola Bay sediments contained high absolute concentrations of arsenic, cadmium, copper, chromium and zinc. However, Apalachicola Bay also has the highest aluminum concentrations of any estuary in Florida with 130,000 ppm (FDER, 1986). Therefore, when absolute concentrations are normalized using metal-to-aluminum ratios, only cadmium, chromium and zinc appear to not be from natural sources (Ryan et al., in prep).

E. Biota and Habitat

The overall high water quality of the Apalachicola estuary, with the combined effects of seasonal flooding, nutrient and detrital transport, and the variable salinity regime, provide ideal living conditions for estuarine biota and result in a highly productive system. The Apalachicola Bay system is comparable to, or higher than, other gulf estuaries in nutrient and detrital transport from the river and floodplain, and in phytoplankton productivity (Estabrook, 1973; Elder and Mattraw, 1982). It is also comparable to other gulf estuaries in its zooplankton production (Edmiston, 1979) and bay anchovy abundance (Sheridan and Livingston, 1979). For many years, the bay has supported the largest oyster harvesting industry in Florida, as well as extensive shrimping and commercial fishing. It is believed that with more extensive cultch plantings and implementation of management and mariculture techniques, the bay could support a substantial increase in production of oysters and other commercial seafood species (Ednoff, 1984).

The following sections will provide background information on the various biological communities that contribute to the high productivity of the Apalachicola estuary.

1. Aquatic Microbiota

Microscopic organisms, including bacteria, fungi, protozoans, and microalgae, are among the most biologically important organisms in the aquatic environment. In estuaries, microorganisms are very abundant and are found in the water column and associated with sediments, detritus, plants, and animals. Most are extremely small, single-celled, and are capable of multiplying rapidly in the water column. They play a part in the recycling of estuarine nutrients, particularly phosphorus (Myers and Iverson, 1977), and, when associated with organic matter and sediments, are vital to the food web of Apalachicola Bay (Livingston, 1983).

The high level of biological productivity in Apalachicola Bay is due in great measure to the nutrient recycling and detrital conditioning done by microbiota (Livingston, 1983). Phytoplankton and aquatic plants depend upon the availability of nutrients in the water for growth; zooplankton and other planktivores use phytoplankton as a primary food source. Many bay organisms, particularly benthic invertebrates, consume detritus during all or part of their life cycle. These animals in turn are part of the food web in which they are preyed upon by omnivores and carnivores. These trophic interactions are based directly or indirectly on the healthy functioning of the microbial community and the quantity, quality, and distribution of detritus.

Communities of microbes are important in the process of decomposition of floodplain leaf litter (Morrison, et al., 1977). By colonizing detrital particles, microbes enhance its food value since the variety and metabolic activity of the colonizing forms provide additional and more diverse proteins and nutrients than were originally available. The enormous quantity and variety of detrital particles (in size, age, state of decomposition, species of plant) in the water column or associated with the substrate provide colonization surfaces for a large microbial biomass in Apalachicola Bay. In the bay the primary surfaces available to microbes are organic litter and sediment particles. Biological disturbance of these substrates by grazing, deposit-feeding, or burrowing, and physical disturbances by winds and tides result in exposure of new substrate to colonizers.

Detrital and nutrient input from upriver are greatest during flooding in late winter to early spring. Although at present no data is available to indicate the seasonal abundance and activity of detrital colonizers, it is likely that most activity takes place during the warmer months when detritus is available, and temperature is not a limiting factor.

Many species of estuarine microorganisms are of public health concern. Bacteria and viruses ubiquitous in the estuarine environment may cause varying degrees of illness in people, via exposure of wounds to waters or sediments, accidental ingestion of water when swimming, or primarily by consumption of seafood which is raw, or improperly cooked or stored.

There are two major groupings of human health-related microorganisms in the estuarine environment: 1) those organisms which occur naturally in the estuary, apparently originating there, such as Aeromonas and Vibrio species of bacteria that are known pathogens; and 2) those organisms which originate in sources external to the estuary, particularly those bacteria and viruses associated with human and other mammalian digestive tracts, and numerous disease organisms. The most important bacteria in this category are the coliform bacteria, including fecal coliforms, which are generally associated with domestic sewage. Also associated with sewage are numerous viruses, particularly enteric viruses. For a more detailted discussion of human health-related microorganisms in Apalachicola Bay refer to Appendix 2.

2. Phytoplankton

The phytoplankton community is an important component of the aquatic system. Phytoplankton live and reproduce suspended in the water column, drifting with the currents. They are photosynthetic and utilize a variety of nutrients in the water, particularly nitrogen and phosphorous.

In Apalachicola Bay the phytoplankton community is dominated by diatoms, single-celled and filamentous algae which have silicious cell-walls. The spatial and seasonal distribution of phytoplankton is patchy, and different species become dominant in different locations and seasons. In Apalachicola Bay proper, Chaetoceros lorenzianum, a marine form, is most abundant, while in East Bay, Melosira granulatum, a freshwater diatom, predominates (Estabrook, 1973).

The Apalachicola Bay system has a moderately high level of phytoplankton productivity compared to other gulf estuaries (Livingston, et al., 1976). Average daily carbon 14 productivity measured ranged from 63 to 1694 mg C/m^2 /day, with an annual productivity of 371 g C/m^2 (Estabrook, 1973). Productivity is seasonal with peaks occurring in late spring and in fall. Lowest levels of production occur in winter when temperatures are lowest and freshwater discharge from the river is high. Although nutrient availability is highest under these circumstances, nutrient uptake and growth is limited by low temperatures. Increases in productivity, therefore, coincide with rising water temperatures in spring.

Nitrogen is not a limiting factor to phytoplankton productivity in the estuary at any time of the year (Estabrook, 1973). It is, however, far more abundant in the cold, growth-restrictive months, and can be low in summer. Nutrient enrichment experiments by Myers and Iverson (1977) indicated that phytoplankton productivity was enhanced only when water temperature was above 21.5°C and nitrate and phosphate concentrations were low. These experiments indicate that low water temperatures limit phytoplankton growth in the winter and low nutrient concentrations limit growth in the summer. Their data also suggest that a reduction in phosphate concentrations during the summer months could reduce phytoplankton productivity.

Phosphate levels are relatively low in the Apalachicola drainage basin, and phosphate is the most critical limiting nutrient for phytoplankton growth (Myers and Iverson, 1977). It adsorbs to fine sediments so that when the bay is well-mixed by winds and the sediments are resuspended, phosphate is released and becomes available for use by phytoplankton in the upper lighted layer of water where photosynthesis can occur.

3. Zooplankton and Ichthyoplankton

The zooplankton community is an association of small aquatic animals that have limited swimming abilities and live suspended in the water column. It includes egg and larval stages of some animals which as adults are not plankton, such as oysters, shrimp, crabs, and fishes. It also includes species that are planktonic through all stages of their lives, such as the calanoid copepods. Zooplankton may be herbivorous, grazing on the abundant but patchy phytoplankton; carnivorous, consuming other planktonic forms; or omnivorous, feeding on almost anything organic including detritus.

In Apalachicola Bay zooplankton biomass, numbers, and species composition was found to be comparable to that of other gulf estuaries (Edmiston, 1979). In this study zooplankton populations from three areas of increasing salinity were compared: East Bay, Apalachicola Bay, and the gulf outside Sikes Cut. Calanoid copepods made up most of the catch, ranging from 70% to 94% of the total at the three sites. In all three areas Acartia tonsa, was the most prevalent organism. Zooplankton numbers and biomass were lowest in East Bay, intermediate offshore, and highest in Apalachicola Bay, with a total zooplankton community average of 9054 individuals per cubic meter and a total Acartia tonsa average of 6304 individuals per cubic meter (Edmiston, 1979).

Seasonally, abundance increased with water temperature, with numbers and biomass starting to rise in March, peaking in May, and declining in October when water temperature decreased. The major differences in distribution were found to be related to salinity. East Bay, which had the greatest fluctuations in salinity, had the lowest numbers, biomass, and diversity of species (92% were Acartia tonsa). The offshore station, with the highest salinities and least fluctuation, had the greatest diversity (only 20% Acartia tonsa). Apalachicola Bay had intermediate diversity (70% Acartia tonsa) and provided the optimum salinity range for Acartia tonsa (Edmiston, 1979).

Other important components of the zooplankton community were barnacle larvae, decapod crustacean (shrimps and crabs) larvae cladocerans, mollusc larvae, larvaceans, chaetognaths, polychaetes, and fish eggs and larvae.

Larval fish and eggs were sampled from the same sites as the above zooplankton study in an ichthyoplankton survey of Apalachicola Bay from November, 1973, to December, 1974 (Blanchet, 1979). The most abundant species collected was the bay anchovy, representing 75% of total larvae and 92% of the eggs caught. The bay anchovy was found year-round, but dominated the warm-season assemblage of species (most collected between April and October). Other abundant larvae found in the summer months were the tidewater silversides (Atherinidae), skilletfish, and gobies. Another group of species was found in the winter months and was dominated by post-larval croaker, menhaden, and spot.

This survey was designed to collect only the larvae and eggs drifting in the surface layers of water. The study indicates that the bay serves as a spawning ground for bay anchovies since both eggs and larvae were found. The only other pelagic eggs collected in the bay were those of the silver perch and the speckled trout. The eggs of other bay-spawning species, such as the silversides, skilletfish, and gobies, may have been under-represented in this survey because they have demersal, attached eggs which would not be available to surface plankton tows. Most species with pelagic eggs are offshore breeders such as croakers and spot. Their larvae develop and grow offshore, arriving in the estuary in the post-larval stage. The non-anchovy eggs identified in this survey were collected near the passes and inlets to the gulf indicating that they were being carried in by the tides (Blanchet, 1979).

4. Benthic Invertebrates

Three major habitat types support populations of aquatic invertebrates in the Apalachicola Bay system: 1) soft mud and sandy sediments, 2) grassbeds and areas of detrital accumulations, and 3) oyster bars. The soft sediment habitat is the most extensive of the three, covering approximately 78% of the total open water area (Livingston, 1984). Many benthic invertebrates, primarily polychaetes and amphipods, inhabit the soft sediments, using them as a burrowing and feeding substrate. Benthic community structure and distribution vary throughout the system, and are determined by the relative composition of the sediment (clay, silt, sand, and shell) and its organic content; by the proximity to runoff, currents, wave energy, and bedload transport; and by water quality conditions (Livingston, 1984). Organisms themselves affect the nature of the sediment by burrowing, tube-building, grazing, and filter-feeding activities. The sediments are a rich source of food, containing bacteria adsorbed onto sediment particles as well as the nutrients and detritus brought in from the river which are the basis of the estuary's food web.

Grassbeds are a complex habitat, providing food and shelter for many organisms. Invertebrate assemblages in freshwater grassbeds are dominated by polychaetes, amphipods, chironomid larvae and molluscs. In higher-salinity grassbeds tanaids, polychaetes, amphipods and oligochaetes are abundant (Livingston, 1984). Grassbeds provide a protected habitat with reduced water turbulence, high dissolved oxygen, and an abundant source of food. The vegetation also provides attachment sites for epiphytes and epifauna, traps and produces detritus, and may be consumed. The grassbeds of the Apalachicola Bay system are therefore utilized extensively by many species, particularly as nursery and feeding grounds.

The oyster bars and lumps of Apalachicola Bay cover approximately 7% of the total bay area (Livingston, 1984).

As substrate, they provide a hard surface for the settling of sessile organisms such as oysters, mussels, anemones, tunicates, and attached algae such as _Ulva_, _Enteromorpha_, and _Gracilaria spp_. (Pearse and Wharton, 1938). The rough structure of oyster reefs, with their cavities and empty shells, is used as microhabitat by numerous motile creatures. Among the more prevalent inhabitants on Apalachicola Bay oyster bars are polychaete worms, isopods, amphipods, mud crabs, hermit crabs, chitons, and barnacles (Pearse and Wharton, 1938). Small benthic fishes like gobies, blennies, clingfishes, and toadfishes reside and/or nest in empty shells and holes. Many oyster predators live on or near the bars while other organisms use oyster shell as substrate for burrowing, or participate in some other sort of symbiotic relationship with oysters.

Benthic invertebrates may be classified according to their life-style. Infauna are generally quite small and burrow in the sediments, remaining relatively sessile. Epifauna live on the surface of the substrate (although they may burrow) and many are capable of migrating great distances, such as penaeid shrimp and blue crabs. Oysters and mussels are also epifauna, yet they are attached and completely sessile as juveniles and adults.

The infauna of Apalachicola Bay consist primarily of small polychaetes and crustaceans (Livingston, et al., 1977; Livingston, 1983). Polychaetes are particularly abundant in the finer muds and grassflats, although they are found bay-wide, most being eurythermal and euryhaline. Two of the most abundant polychaetes are _Mediomastus ambiseta_ and _Streblospio benedicti_. Their populations fluctuate greatly on both a seasonal and annual basis. Most Apalachicola Bay polychaete species are deposit feeders consuming fine detritus, benthic algae, and small organisms living within the sediment.

Infaunal crustaceans such as small amphipods, isopods, and tanaids are also extremely abundant throughout Apalachicola Bay (Livingston, 1983). Many construct small tubes in the sediment in which to live, and consume benthic diatoms and detritus. Amphipods reach highest numerical abundance in late winter and early spring when river-derived organic detritus is arriving in peak quantities to the bay. The major amphipod species are Grandidierella bonnieroides, Ampelisca vadorum, and Corophium louisianum. They are most prevalent in the mudflats of East Bay and the Halodule wrightii grassbeds off St. George Island. This grassbed area also supports a population of one of the most abundant infaunal crustaceans of the bay, Hargeria rapax, a tanaid. It builds tubes in the substrate or on the grasses and consumes fine particles of detritus and benthic diatoms.

Associations of infaunal animals inhabiting leaf litter were studied experimentally in the bay with leaf litter baskets and packs designed to resemble Apalachicola River derived detritus (Livingston, et al., 1977). The major organisms found to inhabit such packs were isopods, (e.g., Munna reynoldsi); amphipods (e.g., Grandidierella bonnieroides, and Gammarus spp.); decapod crustaceans, and a snail (Neritina reclivata). These animals used the leaf litter both for substrate to live in and for food. Most were detritivores or ominvores, and their patterns of dominance

TABLE 4

Summary of Selected Franklin County Shellfish Landings (1975-1985)

	Blue Crabs	Oysters	Shrimp	Total Shellfish
1975				
Quantity[1]	1,659	2,033	4,486	9,000
Value[2]	224	1,107	4,300	6,061
1976				
Quantity	1,742	2,503	3,160	9,679
Value	300	1,591	4,570	7,837
1977				
Quantity	1,106	3,894	4,420	9,822
Value	214	2,820	5,051	8,305
1978				
Quantity	888	5,566	4,931	11,885
Value	189	4,222	5,786	10,441
1979				
Quantity	1,219	5,810	2,714	9,883
Value	243	4,869	5,260	10,464
1980				
Quantity	1,313	6,410	2,890	11,163
Value	280	5,739	4,690	11,077
1981				
Quantity	1,640	6,617	4,788	13,764
Value	374	6,463	7,983	15,307
1982				
Quantity	1,011	4,153	3,047	8,319
Value	275	4,150	6,399	10,933
1983				
Quantity	984	3,936	3,621	8,541
Value	343	4,158	7,956	12,466
1984				
Quantity	1,287	6,199	4,164	11,650
Value	372	6,803	7,985	15,160
1985				
Quantity	1,433	3,786	3,873	9,092
Value	527	4,311	7,154	11,992

Source: Florida Department of Natural Resources, Summary of Florida Commercial Marine Landings.

1. Quantity: in 1,000's of pounds.
2. Value: in 1,000's of dollars.

Florida come from Apalachicola Bay, and historically revenue from this industry has accounted for nearly 50% of Franklin County's income (Whitfield and Beaumariage, 1977). Large oyster bars and numerous small oyster lumps are distributed throughout the bay (Figure 12), and the majority are in areas approved for shellfish harvesting (Figure 13). Additionally, the Department of Natural Resources contributes to the acreage of oyster beds by conducting a shell-planting program. Large quantities of clean shell are placed in suitable locations in the bay providing cultch for oyster spat to settle on and develop.

The American oyster grows faster in Apalachicola Bay than it does in the northern reaches of its range (Ingle and Dawson, 1952). Experiments performed at various sites throughout the bay indicate that spat grow to average lengths of 1.3 inches in six weeks, lengths that may take northern oysters an entire year to achieve (Ingle, 1951). Oysters three inches long may be harvested from cultch after only 18 months (Ingle and Dawson, 1953).

In Apalachicola Bay, the spawning season is longer and more successful when compared to more northern states (Ingle and Dawson, 1953). An increase in water temperature triggers spawning. Some isolated spawning may begin in mid-April at water temperatures as low as 23°C; however, mass spawning, bay-wide, begins at the critical temperature average of 28°C and peaks in intensity in mid-May (Ingle, 1951). Spawning then continues at reduced levels through mid-November.

In Apalachicola Bay, spatfall, or settlement of larvae, often lasts from April to late November. Because spat are planktonic,

Figure 12

LOCATION OF MAJOR OYSTER BARS IN APALACHICOLA BAY

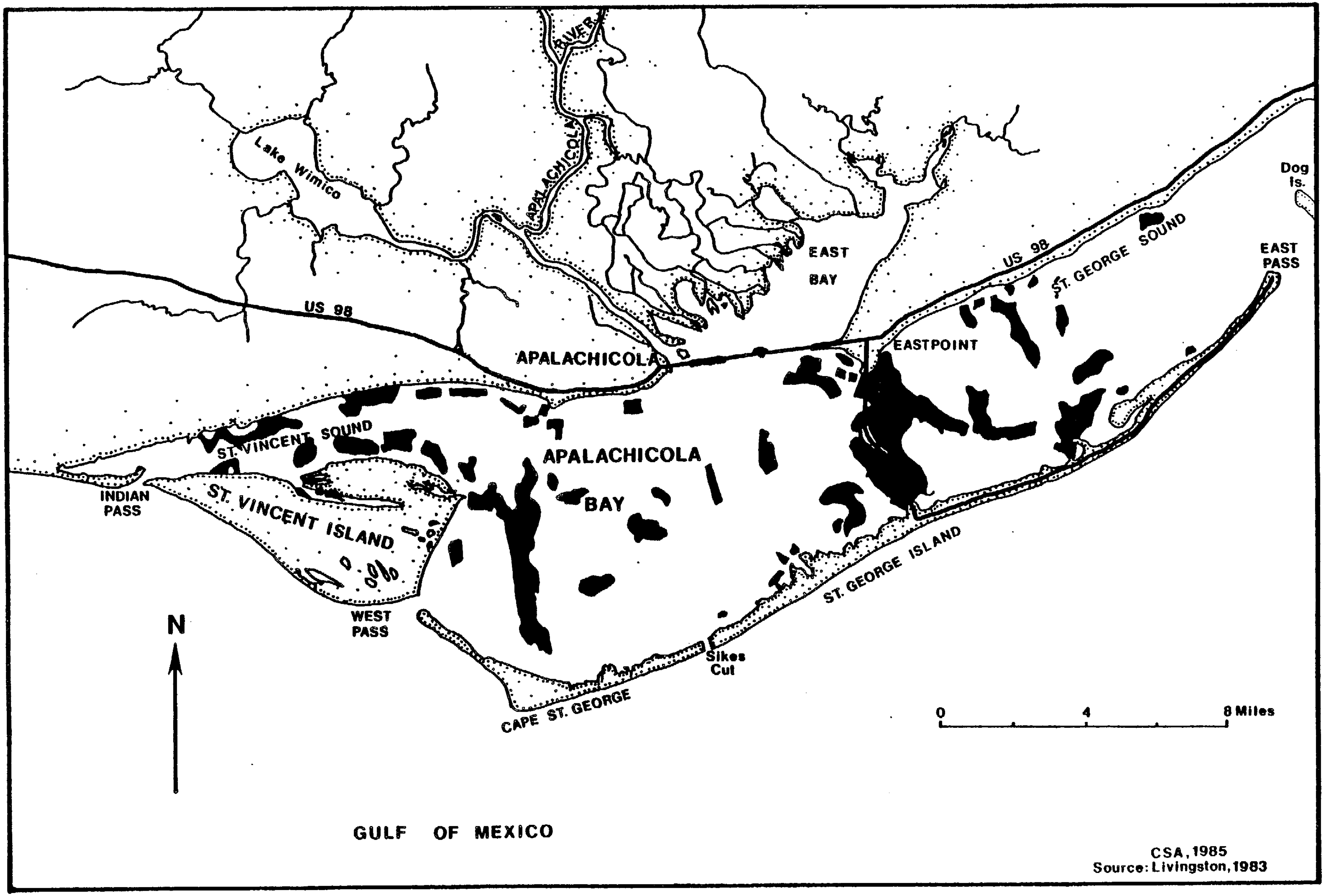
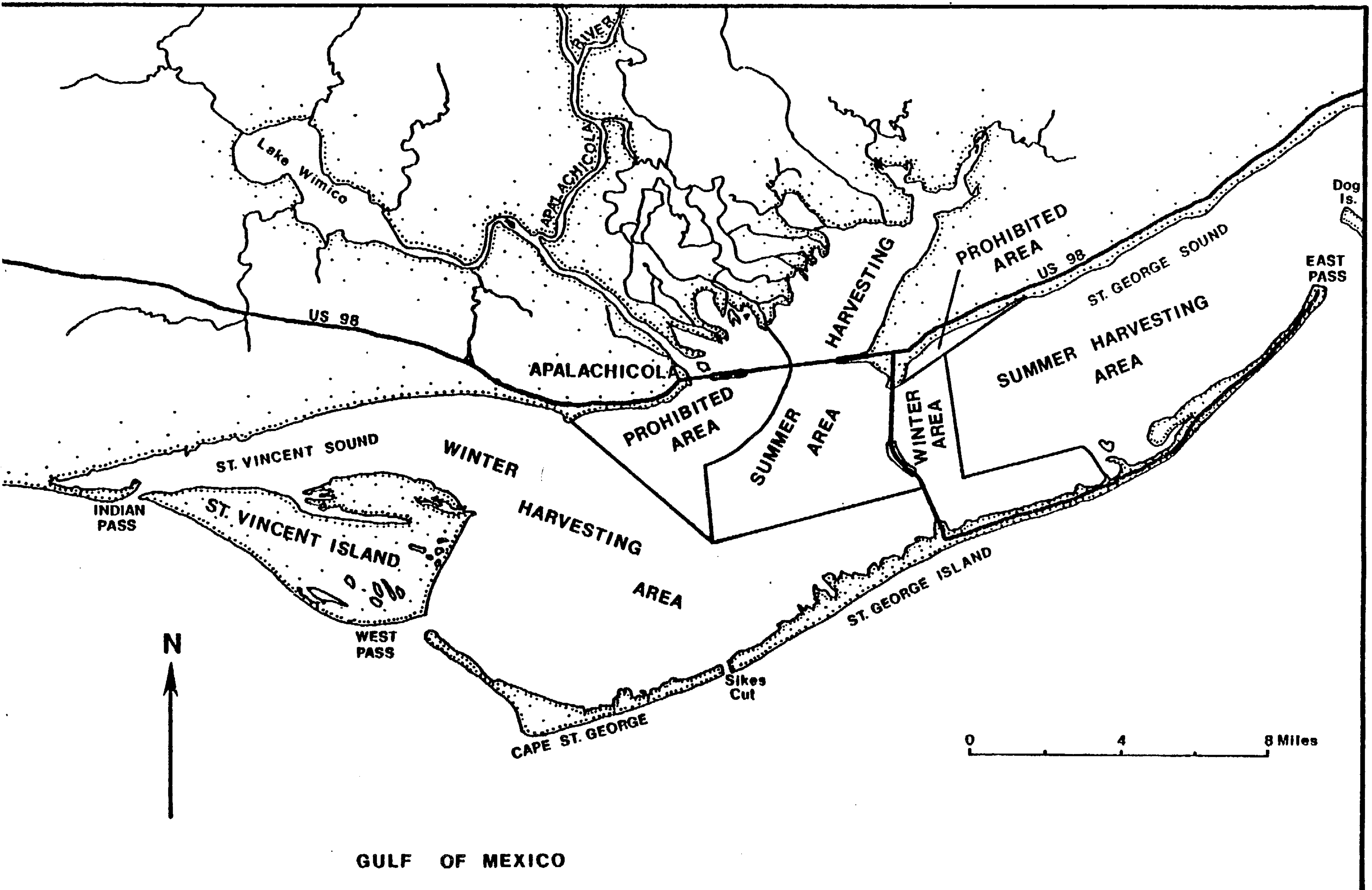


Figure 13

SEASONAL OYSTER HARVESTING AREAS FOR APALACHICOLA BAY



Source: Thompson, et al., 1984

they have a very patchy distribution, and time and location of settlement is highly variable (Ingle and Dawson, 1953). As noted by Menzel, et al. (1966) and Ingle and Dawson (1953), spatfall tends to be less intensive on reefs in lower salinity areas such as East Bay and St. Vincent Sound, and heavier in more saline areas like St. George Sound.

Oysters are most plentiful and in the best condition for harvest during the late fall and winter months, when temperatures are low and salinities are reduced because of high rainfall and riverflow. They have an optimal salinity range of 15-25 ppt (Menzel and Cake, 1969). Oysters thrive in areas of reduced salinity, away from the passes and inlets that allow gulf water (36 ppt) to enter the bay. High summer temperatures raise the oyster's metabolic rate and increase its need for food. With high summer salinities, however, there is less food available and the oyster must pump more to feed itself. The reduced nutritional intake plus the increased expenditure of energy stresses the oyster physiologically, and its condition may deteriorate (Ingle, personal communication). Under these circumstances the oyster is subject to predators and disease organisms which are more prevalent in the summer due to high salinities.

The most serious oyster predators besides man are the southern oyster drill and the stone crab. They have low tolerances for freshwater and are not usually found in salinities below 15 ppt and 12-15 ppt, respectively. Summer conditions permit their encroachment into the bay and onto the oyster bars. In the past when droughts resulted in high persistent salinities, predators have become well-established on oyster bars such as St. Vincent or Dry Bar, and Porter Bar, and consequently these bars were depleted (Menzel,et al., 1958; 1966; interviews with oystermen). A variety of other predators take advantage of the stressed condition of oysters in the summertime; among them are the blue crab, the crown conch, and the whelk.

Hurricanes can have a pronounced impact on oyster bars. Hurricane Elena in September,1985 was estimated by the Florida Department of Natural Resources to have destroyed 80 to 100 percent of the oysters in the highly productive eastern part of the bay (i.e., Cat Point and East Hole). Nick's Hole, off of St. George Island, was also seriously affected. The western bars sustained

varying degrees of damage. The bars were damaged by a combination of churning up and turning over of oyster shells and by direct burial. Some of the higher, inshore bars may have had some freshwater and/or exposure damage. After hurricane Elena, a good fall spat set suggested a rapid recovery for the bay's oyster population. Unfortunately, in November the bay was hit by Hurricane Kate, with winds in excess of 100 mph. Preliminary results indicate the impacts from this storm range from serious, 35% to 70% depletion of post-Elena standing crop, (Livingston, 1985) to minor damage of post-Elena standing crop by the Department of Natural Resources.

b. Penaeid Shrimp

Three species of penaeid shrimp in the Apalachicola estuary are ecologically and economically important to the region. In landing statistics the three species are combined and referred to as saltwater shrimp, and represent between a third and a half of the dollar value of all seafood landings in Franklin County (Table 4). They are the white shrimp, the pink shrimp, and the brown shrimp.

Adult penaeid shrimp migrate offshore to spawn in the Gulf of Mexico, each species having its own spawning season and preferred spawning ground depth (Perez-Farfante, 1969). The eggs hatch offshore, and the larvae develop as they are transported to the estuary by currents. In the low salinity tidal marsh areas where there is protection from predators and abundant food, the larvae develop into juveniles. As their size increases, the juveniles move gradually from the marshes to other parts of the estuary where they become sub-adults (Perez-Farfante, 1969). When water temperatures begin to decrease, they begin the spawning migration offshore to the adult grounds. Those shrimp still not large enough to migrate remain in the deeper parts of the bay until the water warms again in early spring.

The adults stay offshore after the spawning migration and may reach a maximum age of two years (some very large shrimp landed in Apalachicola have been estimated to be about five years of age; Ednoff, personal communication). Most penaeids probably don't survive past 12 to 14 months since they are a prime food source for many aquatic animals and there is high demand for them for human consumption.

The three species of penaeids in Apalachicola Bay have different spawning times, migration patterns, and seasonal abundances. White shrimp are the most abundant in this area. In the long-term trawl data, white shrimp made up over 40% of the total catch (Livingston, 1983; Livingston, et al., 1977), and it is estimated that in commercial bay shrimping landings, they make up to 60% of the average annual shrimp catch (Page, personal communication). Adults have a spawning peak from April to June although they may spawn several times from spring to fall. Post-larval white shrimp move into Apalachicola Bay in spring and summer and may be found in low-salinity vegetated habitat, primarily in East Bay (Livingston, 1983). Juveniles reach peaks of abundance in summer and fall. When temperatures begin to drop late in the year, the white shrimp move offshore, some of them overwintering in the deeper channels and holes of the bay (Livingston, 1983).

Pink shrimp spawn from spring through fall in the gulf and the young return to the bay in summer and fall. They are relatively low in abundance in long-term trawl data; only 5% of the total catch (Livingston, et al., 1977; 1983); however, pinks, or "hoppers" as they are called locally, are important in commercial hauls in the bay (Page, personal communication). Brown shrimp account for only 2 to 3 percent of the long-term trawl data (Livingston, 1983). Commercially, browns are only caught from May to July, and at this time are very large (Page, personal communication).

The seasonality and distribution of penaeids in Apalachicola Bay may be summarized as follows. During the coldest part of winter, relatively few shrimp are taken. By early summer, postlarvae and juveniles arrive in East Bay, apparently attracted to the freshwater mud and grass bottom environment. In July and August the juveniles are at the rivermouth and East Bay. As fall approaches, the center of concentration is still East Bay, but the shrimp begin to move out over the entire estuary, beginning their migration towards the gulf. Penaeid abundance varies greatly, seasonally and annually, in both commercial landings and trawl data (Livingston, 1983).

c. Blue Crab

The blue crab, is one of the most abundant invertebrate species found in the Apalachicola Bay area (Livingston, et al., 1976). Commercial fisheries statistics of Franklin County indicate that blue crabs are the third most abundant invertebrate taken, after oysters and shrimp (Table 4). Blue crabs are also part of an important local sports fishery.

The blue crab is an estuarine-dependent, euryhaline species with a complex life cycle. Mating begins in summer in low-salinity creeks and marshes. Between September and April, egg bearing females from the entire west coast of Florida migrate to a high-salinity gulf spawning site which extends from St. Vincent Island to Panacea (Oesterling and Evink, 1977). Eggs spawned here hatch out and undergo a series of larval stages while drifting with prevailing tides and currents. The developing zoea, megalops, and first crab stages eventually reach estuaries along the southern and western Gulf Coast of Florida. The very early crab stages and juveniles inhabit the estuaries, growing very rapidly, and reach maturity 12-18 months after hatching. Blue crabs then live about one year as adults (Oesterling and Evink, 1977).

In Apalachicola Bay a peak in blue crab numbers is evident in the winter, November through April, when the juveniles arrive (Livingston, et al., 1976). The young prefer low-salinity water, appearing predominantly in East Bay and Nick's Hole. In other northern gulf estuaries, juvenile blue crabs are known to burrow in the soft muds of navigation channels (Overstreet, 1981). It is unknown whether or not juvenile blue crabs burrow in the channels of Apalachicola Bay. Larger crabs are abundant in May and June, and by the late summer and fall months are primarily found in East Bay where the reproductive cycle begins again.

Blue crabs are opportunistic feeders in general, but do show preferences for certain food items at different stages in their development (Laughlin, 1979). Preferences of the larval stages have not been studied closely, but they probably eat single-celled phytoplankton and small zooplankton, as do so many other small planktonic crustacea (Tranter, 1976). Juvenile blue crabs consume detritus, plant material, and molluscs; adult crabs eat fishes and mud crabs (Laughlin, 1982). Enormous quantities of detritus enter the bay from January to April, coinciding with the arrival of the juvenile blue crabs. The large food supply may be the major reason for the large numbers of blue crabs found in the bay.

As pointed out by Oesterling and Evink (1977), the Apalachicola Bay and adjacent Gulf of Mexico is vital to the entire west Florida blue crab industry. Perturbations in water quality and quantity could have far-reaching effects, possibly reducing the number of eggs hatched and the chances of larval survival, ultimately affecting the number of market-sized crabs available on the Florida Gulf Coast.

5. Fish

Available information published on fish populations of Apalachicola Bay comes from two main sources. Dr. R.J. Livingston and the Florida State University Aquatic Study Group have conducted a long-term monitoring study of numerous biological and ecological parameters at permanent sampling stations throughout Apalachicola Bay. Most stations were established in 1972, with some in 1974 (Figure 6). Samples and data were collected on a monthly basis for twelve to thirteen years. Fish were collected with an otter trawl, a small trawl which is dragged relatively slowly and which is most efficient at collecting benthic fishes (often not of very large size) and those pelagic fishes which are not particularly fast swimmers. Trammel nets, gill nets, and seines were used intermittently during the earlier years of sampling and collected some larger, faster swimming species. The top four species collected from 1972 to 1982 were bay anchovies, croaker, sand seatrout and spot in order of numerical abundance (Livingston, 1984).

This extensive fish information is valuable because: 1) it is long-term data from numerous stations representing various habitats; 2) sampling methods used were consistent and regular over time; and 3) it was collected simultaneously with water quality data. Reports by Livingston, et al. (1974; 1976; 1977) and Livingston (1980; 1983; 1984) provide an overview of the trawl-susceptible fish resources and ecology of Apalachicola Bay.

The other data base available on bay fishes is that of the National Marine Fisheries Service (NMFS) which provides Franklin County with annual seafood landings statistics. A NMFS representative visits local seafood dealers three times a week and receives data on pounds of fish delivered by species and the dollar values paid to the fishermen for it. These data are submitted on a voluntary basis, and there is 100% participation by Franklin County seafood dealers (Snell, personal communication; Thompson, personal communication). Table 5 summarizes fish landings for Franklin County from 1971 to 1982.

This data base provides a different perspective on the abundance of certain species from that of the long-term trawl survey. The purposes of each are very different. The long-term trawl survey was designed, in part, to provide an estimate of relative and numerical abundance of demersal fishes. The commercial data reflect abundance in terms of a seafood species' desirability. The types and quantities of seafood landed commercially are influenced by availability, cultural preferences, and marketing. In commercial fishing a variety of gear is used to efficiently capture the desired species. For example, mullet are fast swimmers which congregate in large schools and are caught most efficiently with gill nets. Mullet is the most abundant commercial fish species landed in Franklin County (over 670,000 pounds annually since 1977). It was not represented as an abundant fish in the long term trawl survey, but was collected in trammel net sampling. (Livingston, et al., 1977).

TABLE 5

Summary of Selected Franklin County Finfish Landings (1975-1985)

	Mullet	Flounders	Spotted Seatrout	Redfish	Croaker	Spot	Total Estuarine Finfish	Total Finfish
1975								
Quantity[1]	984	71	74	36	14	13	1,192	1,679
Value[2]	154	23	29	8	<	1	215	400
1976								
Quantity	745	66	101	40	4	4	960	1,472
Value	132	23	43	9	1	<	208	431
1977								
Quantity	539	59	48	22	1	4	673	878
Value	103	25	22	5	<	<	155	268
1978								
Quantity	670	40	49	10	10	3	782	1,060
Value	134	6	25	3	1	<	184	327
1979								
Quantity	645	56	53	11	2	7	774	1,331
Value	118	29	32	4	<	1	184	634
1980								
Quantity	722	90	29	9	3	6	859	1,642
Value	140	47	18	3	1	1	210	954
1981								
Quantity	659	68	51	10	6	4	798	1,663
Value	144	37	33	4	1	1	220	1,164
1982								
Quantity	653	95	55	7	4	10	820	1,907
Value	151	50	38	3	1	2	245	1,414
1983								
Quantity	920	88	55	14	3	13	1093	2,120
Value	210	47	40	6	1	3	307	1,508
1984								
Quantity	896	86	51	9	1	17	1060	1,585
Value	209	49	39	4	<	3	304	961
1985								
Quantity	482	78	47	8	3	4	622	1,103
Value	116	49	38	4	1	1	209	816

Source: Florida Department of Natural Resources, Summaries of Florida Commercial Marine Landings.
1. Quantity: in 1,000's of pounds.
2. Value: in 1,000's of dollars.

A problem inherent in the NMFS data is that actual location of capture is not reported. For instance, grouper and snapper landings in Franklin County are high, yet these could have been caught almost anywhere in the Gulf of Mexico. It is also unknown where fish species that inhabit both the bay and gulf are actually caught. Species landed in significant numbers in Franklin County for which catch location (bay or gulf) is undeterminable include mullet, flounder, red drum, sea trout, shark, menhaden, spot, and croaker. Species caught offshore, and which contribute to Franklin County landings include various species of shark, cobia, bluefish, red snapper, and different species of grouper.

Although these two data bases are totally different in scope and intent, and are not comparable, together they provide an overall perspective on the value of Apalachicola Bay as an important nursery ground, feeding ground, and habitat for estuarine fishes.

It has been estimated that three-fourths of the commercial catch of Franklin County is composed of species dependent on the estuarine habitat and conditions of Apalachicola Bay (Menzel and Cake, 1969). There are various levels of estuarine dependence among the species found in the Apalachicola estuary.

True estuarine species inhabit the estuary throughout their entire life cycle. The most abundant estuarine species in Apalachicola Bay is the bay anchovy. It travels short distances, but makes no long-distance migrations. Other estuarine species tend to remain associated with specific habitats such as oyster bars or submerged vegetation.

Other fish inhabit the estuary during a large part of their life cycle, using it for a nursery and feeding ground. These species include mullet, flounder, and members of the sciaenid family: speckled seatrout, redfish (red drum), croaker, spot, and sand seatrout. The life cycles of these species involve an offshore migration to gulf spawning sites. Developing larvae are transported toward the coast by currents. They arrive in the estuaries and congregate in nursery areas where salinity is low, food is abundant, and predators are relatively scarce. Juveniles of some species mature rapidly and move offshore to spawn within their first year. As adults, they return to the estuary and spend much of their time there (where they are fished commercially in greatest numbers), making annual offshore spawning migrations.

Diadromous species spend a portion of their life cycle in the estuary when migrating to their spawning grounds. In the Apalachicola system, anadromous species (spawning upriver) include the Atlantic sturgeon, the Alabama shad, the skipjack herring, the Atlantic needlefish, and the striped bass. Catadromous species (spawning at sea) include the American eel, the hogchoker, and the mountain mullet (Yerger, 1977).

Other species only enter the bay when conditions are appropriate. With winter and spring flooding and lowered bay salinities bluegill, redear sunfish, and large-mouth bass may enter the upper bay. Other freshwater fish found in the bay include spotted gar, long-nose gar, common carp, and mosquito fish. In summer months, when bay salinities are high, marine fish such as shark, ray, cobia, jack crevalle, grunt, pigfish, and small grouper may enter the bay (Miley, personal communication).

To obtain a perspective on recent fisheries landings in Franklin County, 1971-1982, a table was compiled using the six most valuable estuarine food fish landed: mullet, flounders, spotted seatrout, redfish, croaker, and spot; their combined landings; and total finfish landed, including all species (Table 5). Table 5 shows that all landings declined in 1974, and again in 1977. Since then, the estuarine species landings have risen slightly. Total landings, however, have risen substantially indicating that offshore fisheries (primarily grouper, red snapper, and swordfish) are contributing more to the total catch in recent years. Landings of these three offshore species rose from 151,000 pounds in 1977 (17% of the total landed) to 921,000 pounds in 1982 (48% of the total). Estuarine species contributed 673,000 pounds (77% of the total catch) in 1977, and 820,000 pounds in 1982 (43% of the total landings).

No information currently exists that can adequately explain these fishery trends. It is unknown what the relative contributions of fishing pressure (number of fishermen, concentration on target species, efficiency of gear), natural population fluctuations, and environmental changes are to the overall condition of local fisheries and their ecological relationships.

Appendix 3 presents a review of the life history, abundance, seasonal distribution, and feeding habits of the most important fish species in Apalachicola Bay. Species reviewed in this appendix were selected on the basis of their relative abundances in the long term trawl survey and NMFS data providing they were estuarine dependent species spending all or a major part of their life cycle within the estuary. In order of apparent relative abundance they are: bay anchovy, mullet, flounder, speckled sea trout, redfish, croaker, spot, and sand sea trout.

6. Submerged Vegetation

Aquatic plant distribution in Apalachicola Bay is mostly limited to shallow areas along the coast (Figure 14). Table 6 summarizes the acreage of submersed vegetation assembleges in the estuary. The largest grassbeds in the area are in eastern St. George Sound near Alligator Point and Dog Island, where salinities are generally the highest. These grassbeds consist of shoal grass, manatee grass, and turtle grass. Algal species of the genera Gracilaria, Caulerpa, and Padina also occur here. Further west in Apalachicola Bay, vegetation is limited to the shallow lagoons of St. George Island, and consists primarily of shoal grass, manatee grass, and Gracilaria spp. There is no submerged vegetation at Eastpoint and little or no grassbed development in St. Vincent Sound or along the east coast of St. Vincent Island (Livingston, 1980; 1983).

East Bay supports extensive grassbeds along its marshy perimeter. They are dominated by tape grass, widgeon grass, and sago pondweed all fresh to brackish water species (Livingston, 1980). In recent years, the Eurasian watermilfoil has become rooted throughout northern East Bay, and there is concern over its potential effects on the ecology of the area (Livingston, 1983). A recent study funded by the COE (CSA, 1985) found that Eurasian

Figure 14

SUBMERGED AQUATIC VEGETATION DISTRIBUTION IN APALACHICOLA BAY

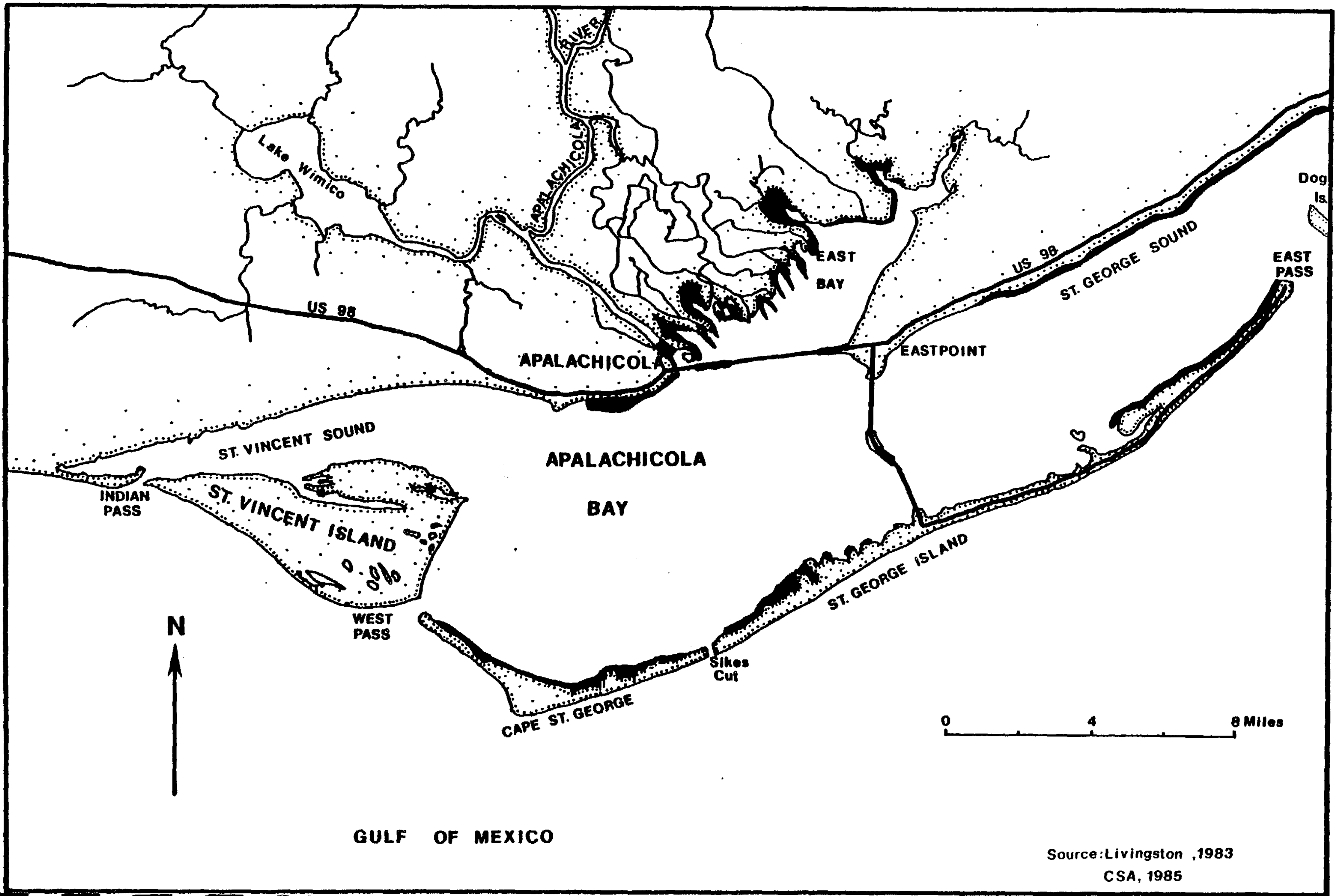


Table 6

ACREAGE OF SUBMERSED VEGETATION ASSEMBLAGES
IN THE APALACHICOLA BAY SYSTEM

Location	Species/Assemblage	Area (Acres)
Apalachicola Bay	_Halodule wrightii_	1,145
	Ruppia maritima _Vallisneria americana_	287
	R. maritima	50
St. Vincent Sound		0
St. George Sound	_H. wrightii_	711
	H. wrightii _Thalassia testudinum_	277
East Bay	_R. maritima_ _V. americana_	166
	Myriopyllum americana _Potamogeton pectinatus_ _V. americana_ _R maritima_	1,179
	Najas guadalupensis	187
	R. maritima	25
	R. maritima, _P. pectinatus_	55

Source: CSA, 1985

watermilfoil has undergone considerable expansion, increasing from 30% coverage in 1980 to 90% coverage in 1985 in the major bays along the west side of East Bay.

Temperature chiefly limits the growth of submerged vegetation in East Bay with plant biomass at its lowest levels during winter months. Significant growth begins when the water gets warmer in early spring, and it peaks between May and July. Senescence and loss of grass blades occurs by August, but some growth may take place in September and October. With winter temperatures, senescence of the grassbed occurs rapidly. A similar seasonal cycle occurs in grassbeds elsewhere in the Apalachicola system, but with greatest growth occurring during the summer and little or no new growth in early fall (Livingston, 1983). While temperature limits the growth of submerged vegetation, salinity affects the distribution. The John Gorrie Bridge and causeway generally acts as a dividing line between higher salinity adapted seagrasses and fresh-to-brackish water species. High salinity species such as turtle, manatee, and shoal grasses have not been found north of the bridge, while fresh-to-brackish water species such as tape and widgeon grasses are not found south of the bridge except near the mouth of the river (Livingston, 1980; CSA, 1985).

Two major evaluations of the grassbeds in the estuary have been conducted in recent years (Livingston, 1980; CSA, 1985). The total area of submersed grassbeds in Livingston (1980) is much higher than that in CSA (1985). CSA (1985) attributes the decline to differences in mapping and area calculation techniques and loss, of grassbeds. CSA (1985) noted little change in species composition in Apalachicola Bay proper, St. George Sound and St. Vincent Sound. However, CSA (1985) did note that both Livingston (1980) and infrared imagery taken in 1979 showed the presence of a large seagrass bed (shoal grass) just west of Sikes Cut, along St. George Island, which was not there when they surveyed the bay.

7. Nursery Habitat

Apalachicola Bay meets the three general criteria established by Joseph (1973) that characterize a nursery ground: 1) an area must provide some protection from predators; 2) it must provide abundant food supply; 3) it must be physiologically suitable in terms of physical and chemical features. A combination of features provide protection from predators in the estuary. The marsh systems along the bay side of St. George Island, the bayous and creeks of St. Vincent Island, and the extensive marshes surrounding East Bay are major areas where post-larvae and juveniles of many species congregate. Salinities in these locations are low since they are areas of freshwater runoff, and in the case of East Bay, heavily influenced by the Apalachicola River. Low salinities are a deterrent to many predatory species (Massmann, 1971).

The structural complexity of vegetation such as widgeon grass, tape grass, shoal grass and turtle grass functions to protect small animals from larger predators (Heck and Orth, 1980). High turbidity and color values found throughout the bay (particularly in areas of freshwater runoff such as East Bay) reduce visibility in the water and may help reduce the effectiveness of those predators that visually seek out their prey. Submerged vegetation has additional protective and nurturing qualities for developing young by providing sheltered microhabitat for benthic, planktonic, and free-swimming organisms, and reduces excessive daytime illumination. The system of leaves, rhizomes, and roots also reduces water turbulence from tides and currents (Kikuchi and Peres, 1977).

The planktonic larval stages of invertebrates and fishes rely on large quantities of phytoplankton and zooplankton (especially copepods in their early life stages) as a food supply (Detwyler and Houde, 1970; Carr and Adams, 1973; Thayer, et al., 1974). The larger post-larval stages may include detritus, other larval forms, epiphytes, and other organisms in their diets (Carr and Adams, 1973; Sheridan, 1978; Laughlin, 1979; Livingston, 1983). In Apalachicola Bay such food types are abundant. Large amounts of detritus are supplied to the bay by the Apalachicola River. The peaks in abundance of these food items in early spring coincide with the early development of the majority of estuarine-dependent species in Apalachicola Bay. As a food resource, submerged vegetation produces a supply of detritus, as well as trapping detritus and other water-borne food items. Grassbeds also provide increased substrate for growth of epiphytic algae and associated fauna which may be fed upon by developing animals (Kikuchi and Peres, 1977).

The temperate climate of Apalachicola Bay provides ideal temperatures for growth and development and a relatively long spring to fall spawning season. The bay circulation system, being wind-driven and fairly well-mixed, provides high levels of dissolved oxygen vital to normal development, and also provides effective waste removal (Livingston, 1983). Additional oxygen is produced by submerged vegetation, which also consumes carbon dioxide (Kikuchi and Peres, 1977). Low salinities, such as those found in the bay, are essential for the proper development of some species (June and Chamberlin, 1958). Cultural eutrophication is still relatively low in Apalachicola Bay; therefore, developing organisms are not stressed by heavy concentrations of pollutants (Livingston, et al., 1974; Livingston, 1983).

8. Intertidal, Marsh, and Terrestrial Biota

Relative to the aquatic communities of Apalachicola Bay, little research has been done on the intertidal, marsh, and terrestrial communities. Several lists of observed plant, bird, and mammal species have been compiled by biologists and wildlife specialists who have made field surveys of Cape St. George State Preserve, the National Wildlife Refuge on St. Vincent Island and other parts of the estuary. A census of island reptiles and amphibians has been published (Blaney, 1971), and an overview of the terrestrial biota of St. George Island is provided in Means (1975).

The intertidal, marsh, and terrestrial community as discussed here is found between the mudflat, beach, and marshy intertidal zone to the coastal uplands along the shore of the mainland and surrounding the barrier islands. The species here are numerous and varied. This area is highly productive, and the species in certain parts of this zone may be submerged or exposed, and experience wide fluctuations in salinity, dissolved oxygen, and temperature, while others may be completely terrestrial.

The animals found here are of two types: permanent and transitory (Heard, 1982). Permanent residents include many invertebrates. The microinvertebrates (meiofauna) living in or on the sediment may include such groups as protozoans, flatworms, roundworms, copepods, ostracods, polychaete larvae, and insect larvae. The macroinvertebrate fauna include polychaetes, oligochaetes, molluscs, crustaceans, and insects (Heard, 1982). Vertebrates who live permanently in this area include muskrats, alligators, turtles, and numerous birds. Other inhabitants visit the intertidal-terrestrial zone temporarily, usually when feeding or nesting. Carnivores and omnivores such as raccoons, mice, blue crabs, fishes, penaeid shrimp, herons, and other water birds feed in this area (Heard, 1982).

Although the invertebrates of the intertidal, marsh, and terrestrial zone have not been investigated per se, leaf-litter and core studies (Livingston, et al., 1977) and fish gut analyses (Sheridan, 1978; 1979) have produced some information on aquatic larval stages of the non-biting midges (the Chironomidae) that are abundant as adults in the marsh and terrestrial zone. The larvae are benthic and are generally found in fresher water in shallow areas and are a food item for many estuarine fishes. No terrestrial insect data exists for the area; however, insects are a significant part of the terrestrial biota, particularly the mosquitos and no-see-ums (local residents, personal communication). Mosquito larvae are also aquatic, live in the water column, and are often fed upon by estuarine fishes.

a. Emergent Vegetation

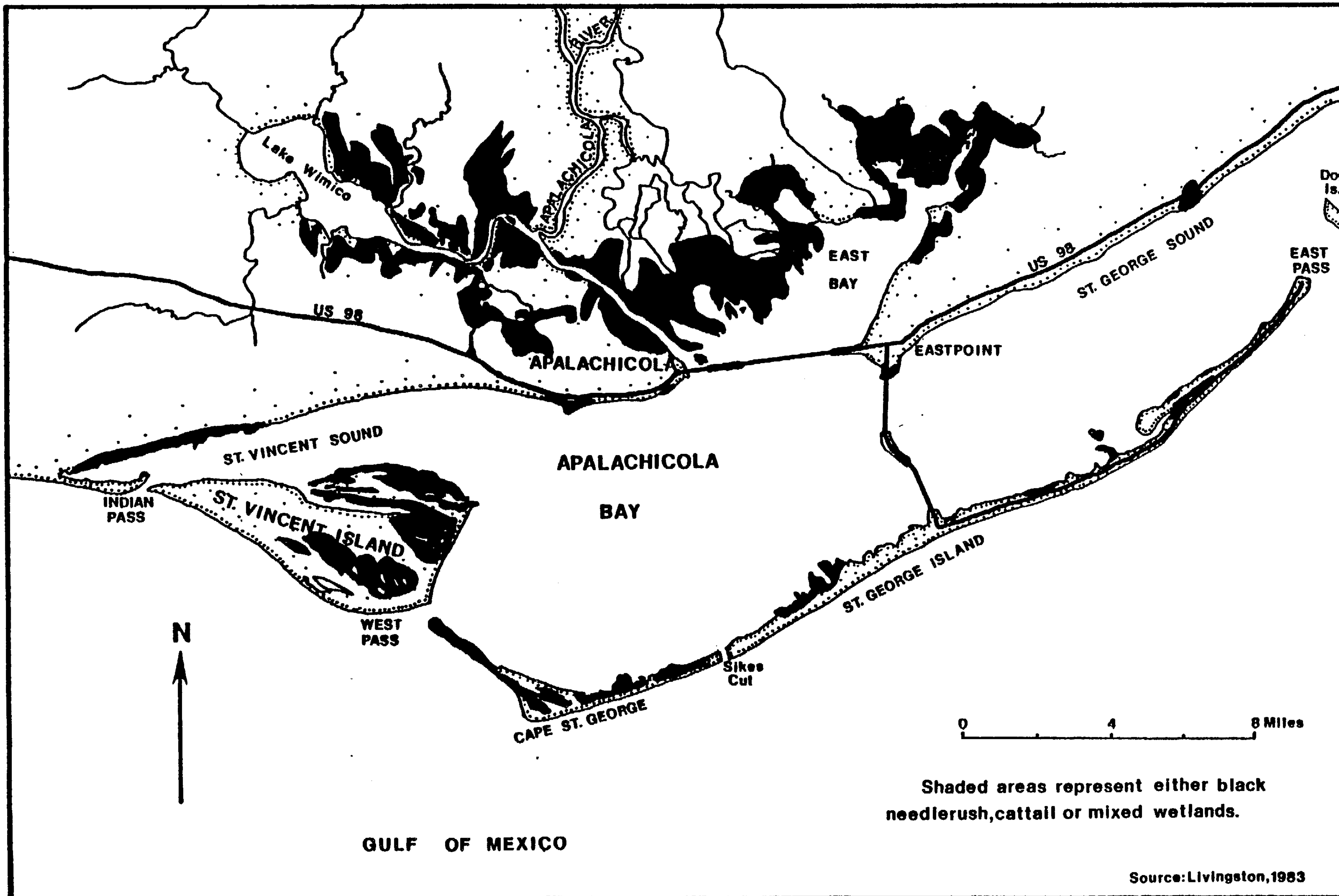
The most extensive marshes in the Apalachicola Bay system are located in the Apalachicola River floodplain near the rivermouth and surrounding northern East Bay (Figure 15). Predominantly freshwater marsh vegetation grows here, dominated by cattails, bullrushes, sawgrass, needlerush, and brackish water forms of cordgrass (Livingston, 1983). A system of creeks and bayous on northeastern St. Vincent Island supports an extensive brackish water marsh. Lagoons along the bay side of St. George Island (such as Nick's Hole and Rattlesnake Cove), Dog Island, and Alligator Harbor are surrounded by saltwater marsh vegetation dominated by needlerush and cordgrass. Marshes cover about 14% of the total aquatic area of the Apalachicola Bay system (Livingston, 1980).

b. Herpetofauna

The coastal marsh environment of the mainland and barrier islands surrounding Apalachicola Bay provides habitat for numerous reptiles and amphibians. A common marsh inhabitant is the American alligator, which is listed as a threatened species of special concern by the Florida Game and Freshwater Fish Commission. The saltmarsh water snake, and the diamond back terrapin, also inhabit marshes of the Apalachicola system (Means, 1977). A census and biogeographic analysis of amphibians and reptiles was conducted by Blaney (1971) on the barrier island chain (Dog Island, St. George Island, and St. Vincent Island).

Figure 15

EMERGENT AQUATIC VEGETATION DISTRIBUTION IN APALACHICOLA BAY



Shaded areas represent either black needlerush,cattail or mixed wetlands.

Source: Livingston, 1983

Thirty species of herpetofauna were found. Among these is the island glass lizard, which is found on St. George Island. Otherwise this lizard is only found on peninsular Florida. This distribution suggests that the Apalachicola Region was the westernmost limit of peninsular Florida species distribution during Pleistocene sea-level fluctuations, and also indicates that island populations have historically been isolated from the adjacent mainland (Blaney, 1971).

The loggerhead sea turtle, a state and federally listed threatened species, nests on the gulf beaches of St. George Island and Cape St. George (Miley, personal communication).

c. **Birds**

Cole (1985) identified 282 bird species within the boundaries of the Apalachicola National Estuarine Reserve (formerly the National Estuarine Sanctuary). This total is a very high species count for such a relatively small area but may be explained by the natural elements within the estuary. The habitats within the Reserve include cypress swamplands, deciduous and coniferous forests of the Apalachicola River floodplain, delicate brackish marshes which are the basis for the estuarine system, and extensive dunes, beaches, and savannahs found in the barrier island system. All of these habitats support a variety of plant communities and are thus capable of supporting large animal populations.

The Apalachicola River estuary lies on the eastern fringe of the Mississippi migratory flyway and thus receives large numbers of birds from both the Midwest and the Atlantic seaboard which use the Gulf of Mexico and peninsular Florida in migration. The Reserve's two barrier islands (St. George Island and St. Vincent Island) in addition to the Apalachicola River form a very unique system that creates adequate landmarks to birds in migration. Therefore, in both spring and fall the barrier islands serve as vital resting spots for birds flying across the gulf states. The estuary's strategic position between two major migratory flyways, at the mouth of a major river system with a large barrier island system accounts for 164 of the bird species identified in the reserve. Of the remaining species, 99 are breeding birds and 20 are non-breeding, summer residential birds. Local residents include many shorebirds, wading birds, and water birds as well as passerines and other more land-oriented species.

Bird species legally listed as endangered, threatened, or of special concern that live, breed and nest within the estuary include the osprey and bald eagle (Miley, personal communication). Many brown pelicans (a federal listed endangered species) inhabit the bay area, but are not known to breed locally. Their nests have been found nearby on islands in St. Joseph Bay (Nesbitt, et al., 1977; Miley, personal communication).

Of particular interest to this study are the habitats provide by construction of the Two Mile Breakwater, the Eastpoint Breakwater, the bridge causeways, and the beach spoil sites at Sikes Cut. Dredge spoil islands in southern Florida have provided nesting habitat for numerous bird species, particularly the royal, tern, and others such as the least tern, laughing gull and black skimmers (Barbour, et al., 1976). These seabirds prefer to nest on sandy open stretches which are inaccessible to humans and mammalian predators, and which are located near estuaries. It is unknown to what extent local breakwaters, causeways, and spoil sites are used for nesting or roosting by local birds. Pelicans and gulls are often seen on the rocky Eastpoint Breakwater, and numerous terns, gulls, skimmers, and oyster-catchers have been observed on the bridge causeways.

d. Mammals

Among the many species of mammals on the mainland, several are commonly hunted, including white-tailed deer, hogs, fox squirrels, and grey squirrels (Frankenberger and Belden, 1976). Other species of mammals found in the area include black bear, raccoon, opossum, marsh rabbit, rats and the eastern mole. Otters were once trapped in Franklin County for their fur. A subspecies of the round-tailed muskrat, found in the lower Apalachicola River floodplain, is a species of special concern (Means, 1977).

The barrier islands are inhabited by similar mammal species. On Cape St. George, marsh rabbits, cotton rats, striped skunks, raccons and grey squirrels have been observed (FDNR, 1983). St. Vincent Island was owned privately in the past and used as a game preserve by an individual who imported exotic game species for hunting. At this date only the sambar deer remains. Other "known or suspected" mammals on St. Vincent Island include opossum, moles, many species of bats, raccoons, feral hogs, marsh rabbits, rats, mice, grey squirrels, round-tailed muskrats, grey foxes, bobcats, river otters, and white-tailed deer. Dolphin are often present in the bay and inshore gulf area, usually travelling in groups. A few manatees have also been observed in the estuary.

F. Protective Actions

Because of the ecological and environmental importance of the Apalachicola estuary, a number of protective designations have given to it. Among these are the designation of the estuary as an aquatic preserve, an Outstanding Florida Water, a National Estuarine Reserve and a Man and the Biosphere Reserve.

Under Chapter 258 of the Florida Statues those waters in Apalachicola Bay from St. George Island bridge west to Indian Pass in Gulf County and North into East Bay are an aquatic preserve. As an aquatic preserve, the state has added authority to review all requests for uses of or directly affecting state-owned sovereignty submerged lands. This mechanism allows for the evaluation of public interest and project merit within the context of environmental impacts upon the preserve. A management plan for the Apalachicola Bay aquatic preserve has not been developed.

Under Chapter 17-3, Florida Administrative Code, the Apalachicola River and Bay are declared as Outstanding Florida Waters (OFW). As an OFW, ambient conditions, instead of prescribed values, become the water quality standards for the water body. An OFW designation is the highest degree of protection affordable under Florida law.

In 1979 the lower Apalachicola River and Apalachicola Bay were declared a National Estuarine Reserve (formerly National Estuarine Sanctuary). As an estuarine reserve funds are provided to purchase lands for preservation and protection, research and education programs are developed, and a mechanism for coordinating management activities is provided. The estuarine reserve program provides no additional authority to manage or protect the resources of the estuary. A management plan for the Estuarine Reserve is currently being developed.

In 1984 the lower Apalachicola River Valley was accepted for inclusion in the Man and the Biosphere Program. This is a system of international reserves operating under the general guidance of the United Nations Education, Scientific and Cultural Organization (UNESCO). These reserves are selected to conserve a representative diversity of the world's major ecosystems as sites for long-term monitoring, research and related educational activities. The boundaries for the Biosphere Reserve are the same as those for the estuarine reserve.

In addition to providing protective designations, the state and federal government have acquired a sizable amount of land in the lower Apalachicola River and around Apalachicola Bay. St. Vincent Island is a 12,358 acre National Wildlife Refuge. Under the Environmentally Endangered Lands Program the State of Florida purchased 28,045 acres in the lower Apalachicola River and the 2,300 acre Little St. George Island. In additional 1,883 acres on the eastern tip of St. George Island is a state park. Under the Conservation and Recreation Lands Program the State of Florida is purchasing 12,467 acres around East Bay. Another 12,623 acres of land which used to belong to M-K Ranches has been acquired by the state. And, through the Save Our Rivers Program and funds provided by the Nature Conservancy the Northwest Florida Water

Management District purchased 36,000 acres of Apalachicola River floodplain. Figure 16 shows the location of these parcels.

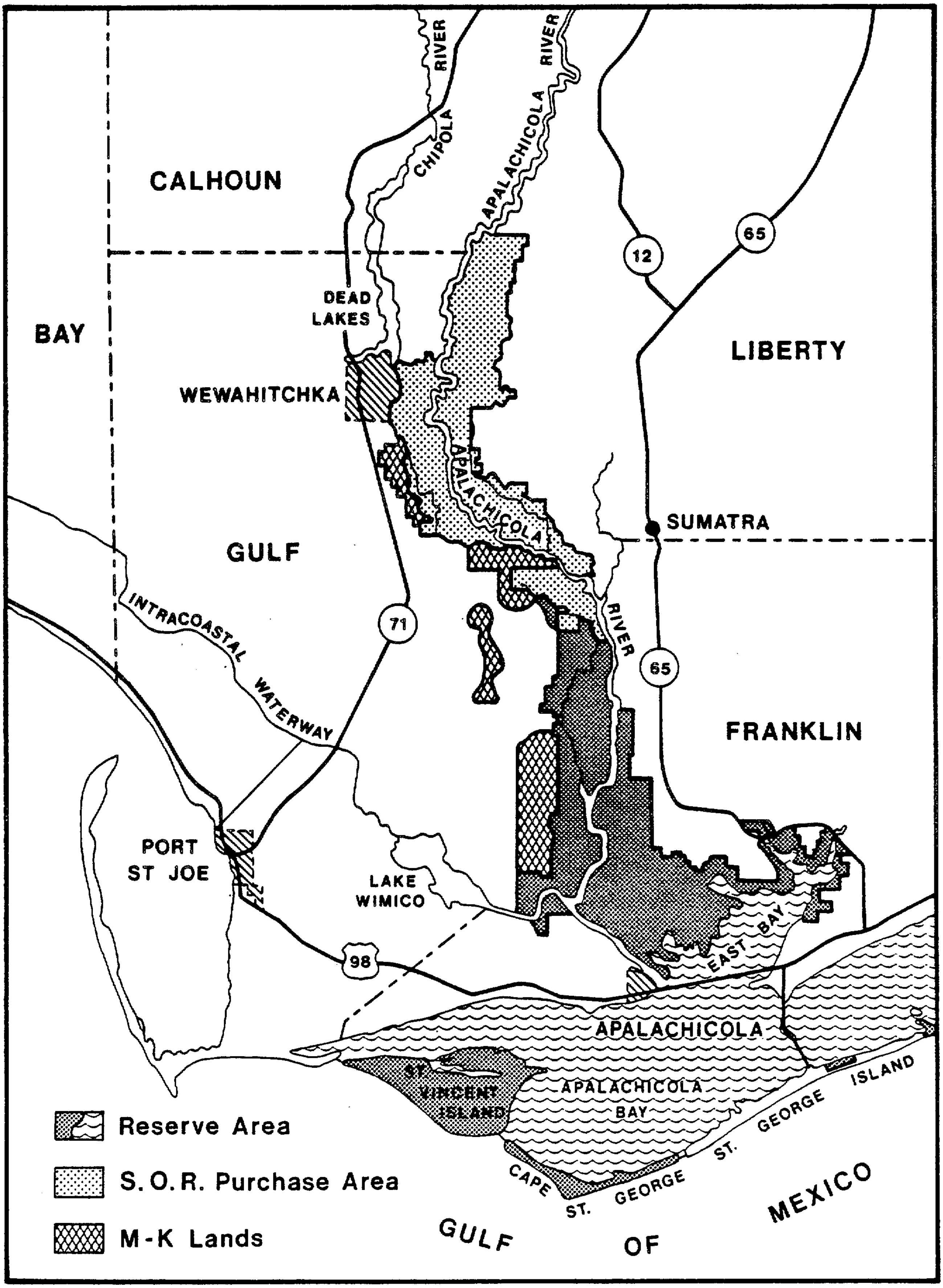
G. Existing Land Use

The major land use in the Apalachicola River floodplain is forestry. Most areas were first cut between 1870 and 1925 and have been logged once or twice since that time. Regrowth has been rapid and much of the floodplain has the general appearance of a mature forest. A few areas of the floodplain have been cleared for agricultural and residential development. The largest agricultural operation in the basin, M-K Ranches, has recently agreed to restore 8,000 of the 10,000 acres of floodplain it had cleared for agriculture to the hydrologic regime of the river.

Population and residential development in the Apalachicola basin is relatively sparce. The combined population of Chattahoochee, Marianna, Sneads, Blountstown, Bristol, Wewahitchka and Apalachicola, the major cities in the basin, is less than 25,000 (Bureau of Economic and Business Research, 1983).

Most of the floodplain land is owned by timber companies. However, a large part of the floodplain is also in the public domain. In conjunction with the Apalachicola River and Bay National Estuarine Reserve approximately 28,000 acres of floodplain in the lower river are under state ownership. Torreya State Park and Ft. Gadsden State Park account for additional 1,140 acres of state-owned floodplain lands. Through the Save Our Rivers program, the Northwest Florida Water Management District has purchased 35,000 acres of floodplain and is negotiating for the

Figure 16
LAND IN THE LOWER APALACHICOLA RIVER BASIN IN PUBLIC OWNERSHIP



purchase of an additional 40,000 acres. And, the Nature Conservancy, a private land trust, has also purchased 4,500 acres of floodplain and adjacent uplands in the upper river basin, and is currently negotiating additional purchases in the basin. According to Section 253.12 of the Florida Statutes,land below the ordinary high water line of the river, and land in tidally influenced areas below mean-high water, are owned by the state. The ordinary high water line is defined as the elevation reached by waters in a usual year for a long and continuous enough period to remove terrestrial vegetation and change soils. The line must also be immediately attached to a navigable water body (D. Thompson, personal communication).

With a few notable exceptions (i.e. cities of Apalachicola and Eastpoint, part of St. George Island and the coastal strand between Eastpoint and Carabelle) the major land uses in the Apalachicola Bay area are forestry and federally or State owned conservation areas.

St. Vincent Island, a triangular shaped barrier island, was a privately owned game preserve until 1968, at which time it was acquired by the U.S. Fish and Wildlife Service, for inclusion in the National Wildlife Refuge System. Land use on the island is limited to outdoor recreation since the 12,358 acre island's primary purpose is to serve as a wildlife refuge.

Running from the east end of St. Vincent Island lies Little St. George and St. George Islands. Little St. George is owned by the State of Florida under the Environmentally Endangered Lands (EEL) program. A little more than half of the land use on St.

George Island is single family residential with some commercial tourist oriented areas. The eastern portion of St. George Island is a State Park. Unit Four, which faces the mainland and rests within the residential portion of the island was purchases by the Trust for Public Land and sold to the State of Florida through the EEL Program.

Across from St. Vincent Island, along the coast and for approximately 18 miles west of Apalachicola the major land use is forestry/silvaculture. This area is sparsely populated. Due west of Apalachicola, is a mobile home development. Apalachicola consists mostly of residential development. The major land uses fringing the city are commercial fishing houses, light industrial and residential.

The major land use surrounding East Bay is forestry/silvaculture and conservation. The City of Eastpoint consists mostly of single family homes and mobile homes/trailers. Along Highway 98 within and just outside of Eastpoint, is a large area used for single family home industry and commercial fishing. From this area to Carabelle, along the coast, south of Highway 98 are single family homes owned by small land owners. To the north of Highway 98 stretching on to Carabelle are mobile homes owned by small land owners.

Most of the population in Franklin County is concentrated along the coastal strand and St. George Island. At present there are approximately 7000 persons residing in the county and this number is expected to increase to 10,000 by the year 2000. In the future, development is expected to occur most heavily along the bay and on St. George Island.

Aside from forestry, residential development is the primary land use in Franklin County. County wide there are 51 recorded subdivision plats; 25 more are unrecorded with a total of 6,822 lots. Currently the majority of these lots are unbuilt and development is contingent upon adequate public services and facilities; 45% of them are on St. George Island.

H. Cultural History

The Apalachicola River Valley is believed to have been occupied by humans for over 10,000 years (Dunbar and Waller, 1983). Little is known of these early inhabitants, other than that they were small, seasonally wide-ranging groups of hunter-gatherers organized in family bands (White, 1984). Their sites generally clustered around river crossings where game could be more easily taken. Because of the arid conditions during the Pleistocene Period, water was an important factor in settlement location. Therefore, the Apalachicola River Valley is believed to have been an ideal environment for small hunting groups. However, no direct evidence of Paleo-indian occupation has been uncovered to date (Henefield and White, 1986).

The Archaic period (7000-1000 B.C.) is only slightly better known than the earlier period of habitation in the Apalachicola River Valley. The type of tools used would indicate an increasing reliance on smaller game animals. Several middle to late Archaic sites are known in the region (Bullen, 1950; Kurjack 1975; Huscher, 1964; and Gibson, et al., 1980; White, 1984). The late

Archaic period is marked by the introduction of fiber tempered pottery, which is probably an independent invention originating in S.E. Georgia, Florida, and Louisiana at nearly the same time (Phelps, 1966; Bullen, 1972). Settlements of a seasonal or semi-permanent nature are noted in the valley during the late Archaic period (just after 3000 B.C.) and these settlements intensively exploited selected resources such as deer, nuts, fish and shellfish. Expanded systems of socioeconomic interaction helped to spread various technological innovations such as new projectible points styles, steatite vessels and fired clay pots (White, 1984).

Human populations became more sedentary by 1000 B.C., engaging in hunting and foraging as well as the beginnings of plant cultivation. In Northwest Florida this period is known as the Deptford period. Although the majority of Deptford sites are associated with coastal swamps and estuaries (Milanich and Fairbanks, 1980), Deptford components have been located at a number of sites in the region (Bullen, 1950; Huscher, 1964, White, 1984). One site on the upper Apalachicola River suggests more than just an occasional occupation with the Deptford component extending several hundred meters along the river bank (White, 1984). The Deptford period is characterized by the appearance of sand tempered ceramics and larger, more settled villages (Hennefield and White, 1986).

The following Swift Creek period, 300 B.C. to 200 A.D., is best known for the paddle-malleated complicated stamped ceramics associated with occupations. This decorative motif originated in central Georgia and radiated rapidly to both the Georgia and Florida coastlines.

The influx of ideas from the north (Hopewell) and from the West (Poverty Point) to the indigenous Florida gulf coastal culture culminated in a vibrant and dynamic set of regional adaptions during the middle Woodland stage known as the Weeden Island culture. By 200 A.D., this culture had spread to the basin (White, 1981). Weeden Island ceramics are the most distinctive and well made in the Florida Gulf Coast and have long been recognized as being among the finest native ceramics in North America (Willey, 1949).

Numerous Weeden Island sites are noted in the region surrounding the Apalachicola River Valley (Brose nd.; Bullen, 1950; Kelly, 1953; Huscher, 1959, 1964; Percy 1971, 1972; Milanich, 1974; Kurjack, 1975; Chase, 1978; White, 1984). Through the Weeden Island period an increasing dependence on agriculture was responsible for a small, but constantly growing population. Sites with multiple burial mounds and extensive middens are noted in the central Apalachicola River Valley by Milanich and Fairbanks (1980), and local sites of this time period have been investigated by Bullen (1950), Kelly (1950), Huscher (1964, 1971), and White (1980). Burial mounds seem to have stopped being built between 500 and 1000 A.D. (Hennefield and White, 1986).

Around 1000 A.D., in response to stresses from increasing populations, the native culture shifted, evidently fairly rapidly, to larger aggregations in more permanent, riverine villages, where a larger labor force could concentrate on an intensified maize culture (White, 1981). These changes developed in local Weeden Island populations as response to constant diffusion of culture traits from Mississippian peoples. This Weeden Island culture is known as the Ft. Walton Culture, which can be dated at 1000 to 1600 A.D.

These Ft. Walton populations were the first to have contact with Spanish explorers which was followed by a chain of Spanish missions organized from 1670 to 1665 (Jones, 1973). This historic phase, dating from 1600 A.D. to 1750 A.D., is known as the Leon-Jefferson period, during which aboriginal settlement patterns were changed by Spanish influences. By the mid-seventeenth century, native cultures were disrupted and populations had declined severely, mostly because of the introduction of european diseases (Hennefield and White, 1986).

Along the Apalachicola during this time, English traders from the central Georgia area sold guns to the local populations, while Spanish traders were not allowed to trade. During the 1680's Spain built three forts in the area: one near the junction of the Chattahoochee and Flint Rivers, another near the present day city of Columbus, Georgia, and one at the confluence of the St. Marks and Wakulla Rivers.

In 1703 and 1704 allied British and Creek forces destroyed all but two of thirteen existing missions of the province of Apalachee and hundreds of Indian captives were taken back to Savannah, effectively depopulating the area (Swanton, 1922). By 1715, returning Creeks resettled the area. With the Treaty of Paris in 1763, Florida passed into English hands for twenty years, then back to the Spanish. Historic Creek sites, all small, are known in the surrounding areas of the valley and have been noted by Fairbanks (1955), and Kurjack (1975).

Continued encroachment by American settlers onto native occupied areas led to increased hostility which culminated in the Red Stick Rebellion (Moore, 1951). Following the war of 1812, and the defeat of the Creeks in 1814, only a few scattered remnants of the Creek nation survived in the Apalachicola area.

The War of 1812 forced colonial powers out of the region and in 1822, Florida joined the union. Subsequently, remnants of the Creek population were forcibly removed and white settlers began to colonize the river valley. Demand for cotton lured many settlers to the rich land, and by the early 1820's, a marketable crop of cotton was being produced in the Apalachicola River Valley. In 1822, the area around the mouth of the Apalachicola River was designated as a customs district. This was the beginning of the community of Apalachicola (Owens, 1966).

In 1827, the first steamboat, the Fanny, visted the community and continued upriver. Unfortunately, she blew up near Columbus, Georgia (Owens, 1966). But, many more boats were to follow. Most of the boats on the A-C-F river system were small to medium size vessels designed for shallow water operation. Although steamboat traffic was seasonal, community dependence on them was heavy because alternative transportation was slow, seasonal and tenuous at best (Grambling, 1980).

Riverboats provided the primary means of transportation and communication along the river system from the 1820's until the turn of the century. By the 1850's, several factors caused a decline in cotton shipments and subsequently, the decline of the riverboat era. Among these were the development of a textile industry in Columbus, increased competition from railroads and the War between the States (Grambling, 1980).

In pre-civil war times the river's floodplain, from the present location of the I-10 bridge to the Chipola Cutoff, functioned as a "little Mississippi River Valley" (Atkins, personal communication). Cotton was grown extensively in the fertile floodplain soils since upland soils were of poor quality and no commercial fertilizers were available. The cotton was grown mostly in locations populated by bottomland hardwoods since the cypress/tupelo content, eventually killed the local satsuma industry. In the late 1800's and early 1900's the floodplain was also used extensively for raising cattle and swine.

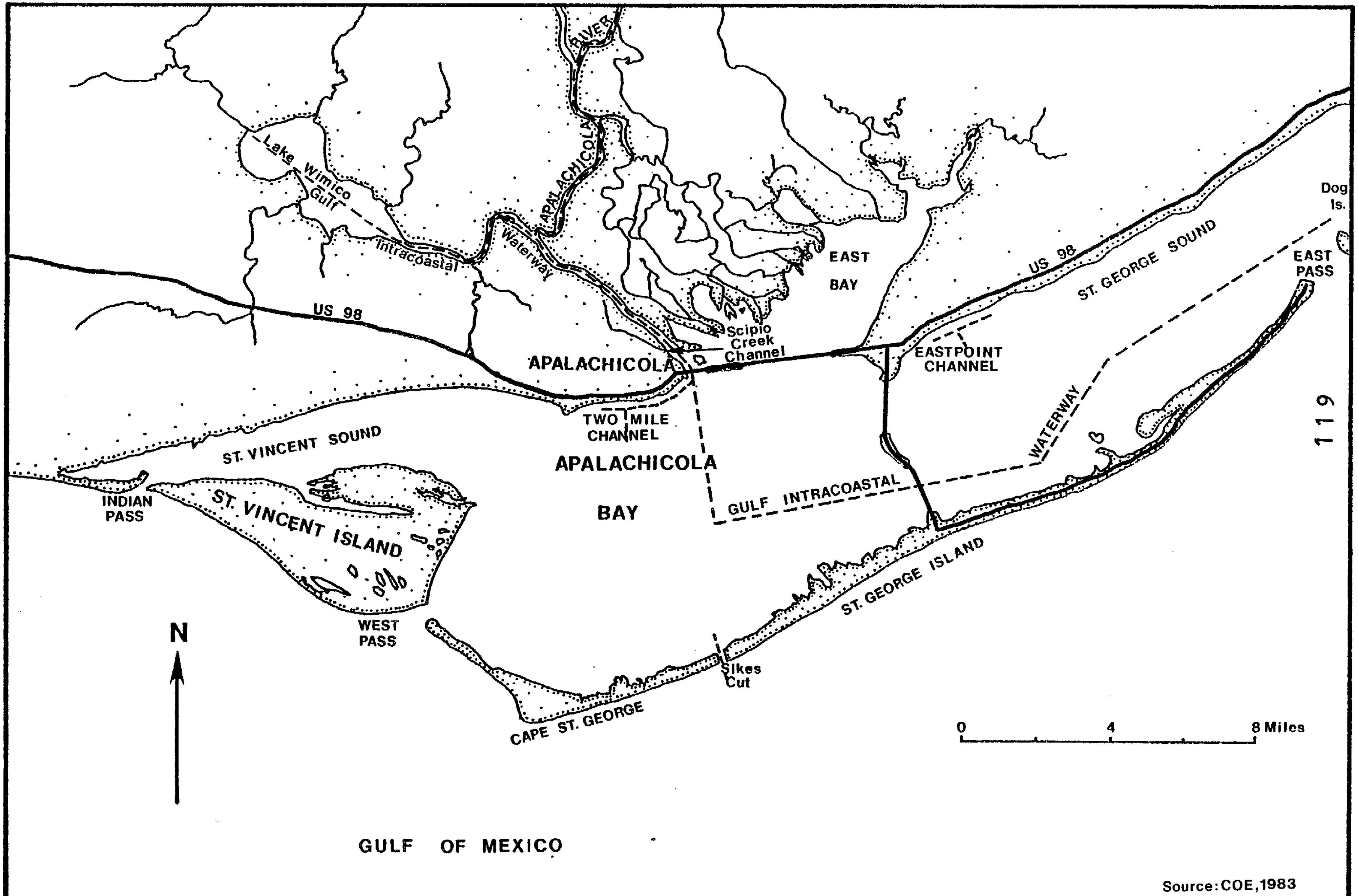
IV. THE AUTHORIZED NAVIGATION PROJECTS

There are several authorized navigation projects in the Apalachicola Bay system including the Gulf Intracoastal Waterway (GIWW), the Two Mile Channel, the Eastpoint Channel, St. George Island Channel and Scipio Creek Channel. Figure 17 shows the location of these projects. In addition, the Apalachicola-Chattahoochee-Flint navigation channel begins at the John Gorrie Bridge and extends up the Apalachicola River system into Georgia and Alabama. A detailed description of this project may be found in FDER (1984). The GIWW is used both for waterborne commerce and as an access channel to Apalachicola for a variety of commercial and recreational fishing interests. Two Mile and Eastpoint Channels are used predominantly by oyster boats, smaller shrimp boats and recreational craft. St. George Island Channel, or Sikes Cut, is used for access to the Gulf by the larger shrimp boats and for recreational fishing. There are roughly 1,150 acres of bay bottom currently approved for as open water disposal and over twenty miles of authorized navigation channels in the bay. This accounts for nearly one percent of the bay bottom.

In reviewing the dredging history of the navigation channels in Apalachicola Bay it should be noted that none of the channels were dredged between 1979 and 1983 since the COE did not have a maintenance dredging permit for either the GIWW or the bay projects (i.e., Two Mile, Eastpoint, Sikes Cut and Scipio Creek) during this period. Since 1979 revisions to the Clean Water Act

Figure 17

AUTHORIZED NAVIGATION PROJECTS IN APALACHICOLA BAY



required the COE obtain water quality certification from the State of Florida before they maintenance dredge a navigation channel within state boundries. The dredging history for the channels in Apalachicola Bay indicates that in anticipation of permitting problems from the Clean Water Act, the COE extensively dredged all the Navigation Channels in the bay in 1978. The GIWW, Two Mile, Eastpoint, and St. George Island Channels all had among their highest quantities dredged (Tables 7,10,11,12).

The COE did not apply for the GIWW permit until 1981 and for bay projects until 1982. The GIWW permit was issued in 1984, but to date the bay projects have not been permitted because the COE has not formally responded to the DER's Completeness Summary. It is anticipated that the COE will try to get these projects permitted in 1986. In 1984 the COE was given a permit to maintenance dredge the St. George Island Channel one time. In addition, the cut was dredged in September 1985 and January 1986 beause of damages caused by Hurricane Elena and Hurricane Kate. Most dredging in Apalachicola Bay is done with a hydraulic cutterhead dredge, although a clamshell dredge has been used for small isolated jobs. Disposal sites for the most part are open-water sites, although an upland site and beach renourishment are also used.

A. Gulf Intracoastal Waterway

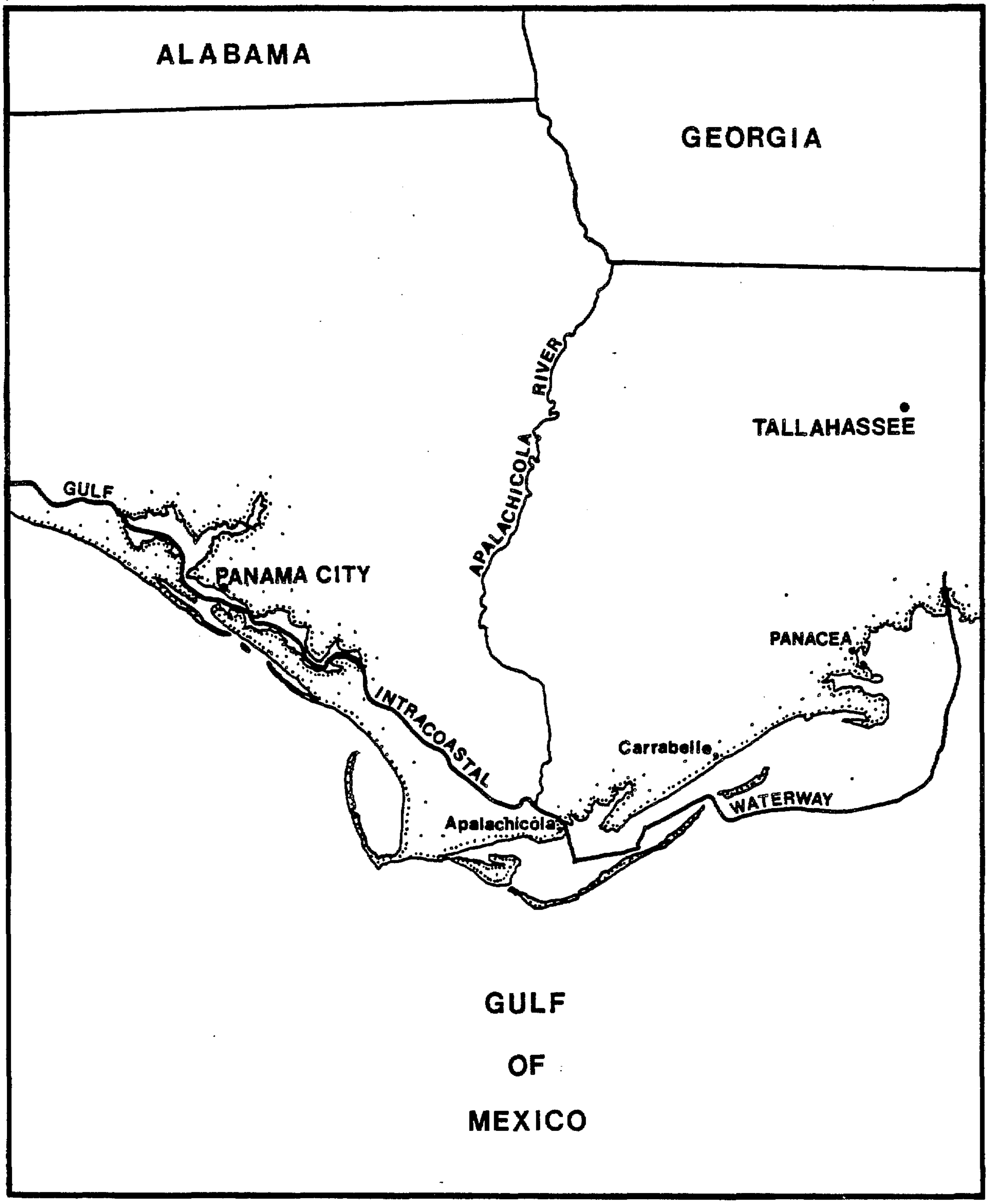
The Gulf Intracoastal Waterway is a shallow draft navigation project which extends 1,115 miles along the Gulf of Mexico coast from northern Florida to the tip of Texas. Although the GIWW is authorized to have a 12 x 125 foot channel to Apalachee Bay, Florida, to date the project has only been constructed to Carrabelle. The authorized inland route from Carrabelle to Apalachee Bay is currently deferred for restudy (COE, 1983) and traffic to St. Marks uses an open water route through East Pass and around Alligator Point. Figure 17 shows the route of the GIWW in the vicinity of Apalachicola Bay, and Figure 18 is a map of the GIWW from Panama City to Apalachee Bay.

The GIWW was constructed to provide a sheltered course along the coast of the Gulf of Mexico for barge tows and other small craft designed for navigating inland waterways but not suitable for the rougher waters of the open gulf. Much of the channel follows protected sounds and bays between the mainland and offshore islands. Some parts traverse open bays, and portions have been cut through land to connect natural bodies of water (COE, 1976).

The GIWW was built in segments, with the first federal act passed in 1828 authorizing the construction of the Pass aux Herons connecting Mobile Bay and Mississippi Sound. In 1909, Congress first directed an investigation of constructing a continuous waterway, inland where practical, along the Gulf of Mexico from St. George Sound to the Mississippi River near New Orleans. With the completion of a canal between Choctawhatchee Bay and St. Andrews Bay in 1938, this inland waterway became a reality. Extension of the channel from Apalachicola through St. George Sound to Carrabelle and then inland to St. Marks was authorized

Figure 18

MAP OF G.I.W.W. FROM PANAMA CITY TO APALACHEE BAY



Source: COE, 1983

in 1937 (COE, 1976).

The north-south leg of what is presently the GIWW in Apalachicola Bay, initially was the Inner Bar Channel authorized for construction in 1880, and first dredged in 1882. The purpose of this channel was to provide access from the open gulf and anchorage areas in Apalachicola Bay to the Apalachicola River. A further discussion of the Inner Bar Channel may be found later in this section.

Table 7 summarizes the dredging history for the GIWW since 1970 and the quantity of disposal at the various disposal sites. Figure 19 shows the location of the disposal sites. Table 7 shows that the GIWW was not dredged from 1979 through 1983 because of permiting problems discussed earlier. A review of COE Report of Channel Conditions for the GIWW indicates there were shoaling problems in the channel over this time period. The majority of the dredging and disposal activity on the GIWW in Apalachicola Bay occurs within two miles of the bend in the GIWW, in the open waters of the bay. All disposal sites used on GIWW project in Apalachicola Bay are open-water sites. There are 815 acres of approved open-water disposal area associated with the GIWW in Apalachicola Bay. Of these, 510 acres are on the east-west leg, and the remainder are on the north-south leg (COE, 1981). It is estimated that open-water disposal sites will satisfy the maintenance dredging needs of the GIWW over the next 20 to 50 years (COE, 1981). At open-water sites the natural shifting of sediments rejuvenates a site and extends its effective life. A review of the dredge monitoring surveys collected in 1984 by the

TABLE 7

HISTORY OF DISPOSAL SITE UTILIZATION
OF THE GIWW, APALACHICOLA BAY

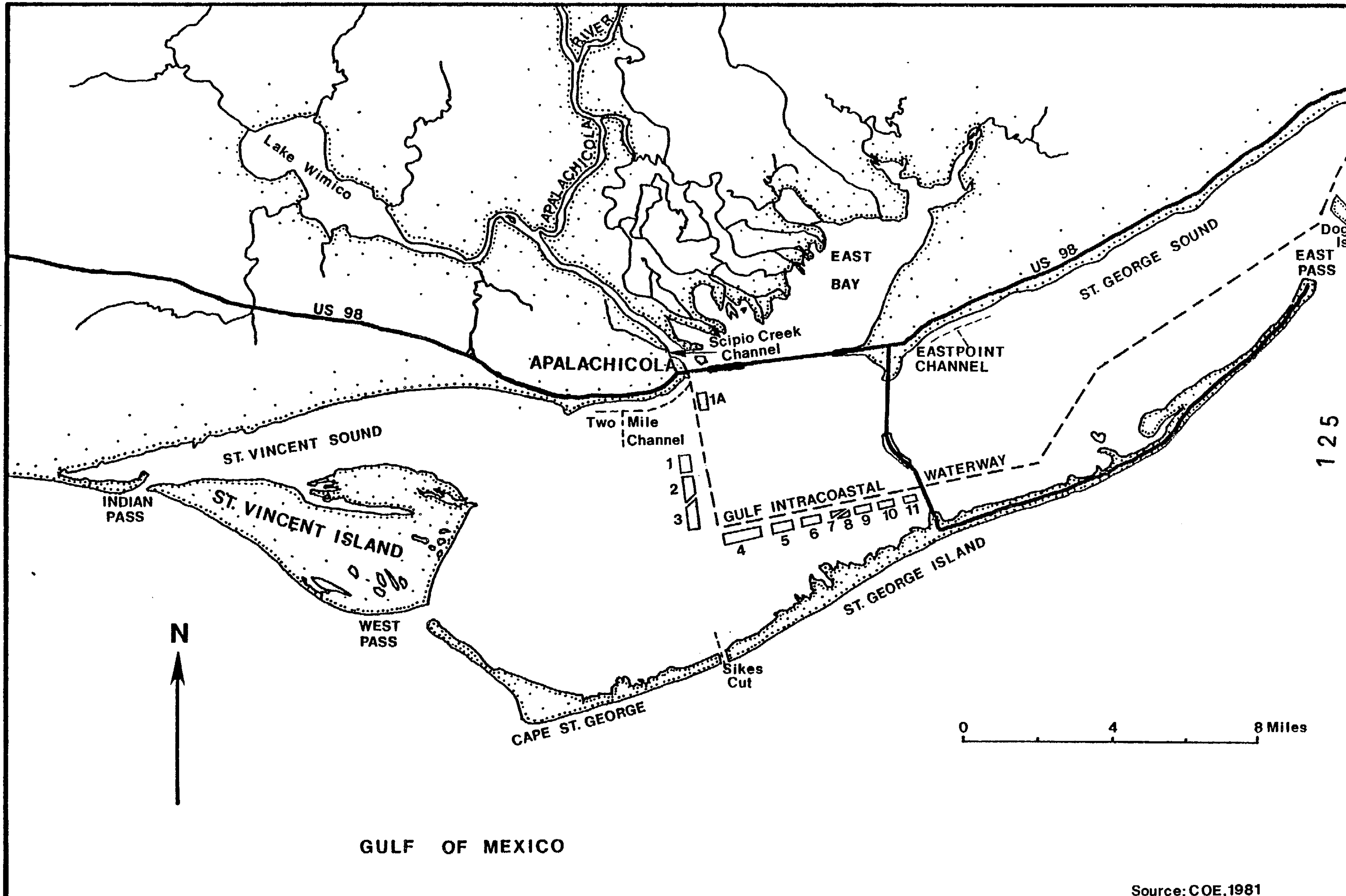
QUANTITY DISPOSED AT EACH DISOSAL SITE (1000's cubic yrds)

Year	1	1A	2	3	4	5	6	7	8	9	10	11	TOTAL
1970	130	---	104	203	16	---	---	---	---	---	---	---	454
1971	147	26	128	300	139	71	32	---	---	---	---	---	844
1972	75	---	66	186	---	---	---	---	---	---	---	---	327
1973	---	---	---	---	---	---	---	---	---	---	---	---	0
1974	---	---	93	167	90	---	---	---	---	---	---	---	350
1975	91	---	73	144	---	---	---	---	---	---	---	---	308
1976	---	60	---	30	225	---	20	31	20	---	---	---	386
1977	33	---	67	91	66	53	---	---	---	---	---	---	311
1978	17	27	169	314	34	---	---	---	34	71	62	49	777
1979	---	---	---	---	---	---	---	---	---	---	---	---	0
1980	---	---	---	---	---	---	---	---	---	---	---	---	0
1981	---	---	---	---	---	---	---	---	---	---	---	---	0
1982	---	---	---	---	---	---	---	---	---	---	---	---	0
1983	---	---	---	---	---	---	---	---	---	---	---	---	0
1984	125	100	257	180	98	87	18	51	110	23	65	---	1114
TOTAL	618	113	800	1692	750	222	139	49	105	181	5	114	4871

SOURCE: COE Daily Dredge Reports

Figure 19

DREDGED MATERIAL DISPOSAL SITES FOR THE GULF INTRACOASTAL WATERWAY



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COE does not indicate any appreciable accumulation of material at the GIWW disposal sites.

The major purpose of the GIWW is the transportation of waterborne commodities along the coast and to the ACF waterway. Table 8 summarizes the major commodities moved on the GIWW between Apalachee Bay and Panama City from 1971 to 1982. These include gasoline, residual and distillate fuel oil, fertilizers, phosphate rock, and sodium hydroxide. However, all the commodities which are shipped on this stretch of the GIWW do not necessarily cross Apalachicola Bay. Some products such as sodium hydroxide are delivered to Port St. Joe, whereas others go up the Apalachicola-Chattahoochee-Flint waterway. Since the GIWW connects with the ACF waterway at the confluence of the Apalachicola and Jackson Rivers, about six miles above John Gorrie Bridge (Figure 16), traffic which goes up the ACF waterway from the west does not cross Apalachicola Bay. From 1971 to 1980 only about twenty percent of the tonnage, about 500,000 tons per year, actually traversed Apalachicola Bay. Principle commodities shipped over the bay in this time period included gasoline, phosphate rock, asphalt, tar and pitches, and sodium hydroxide. In 1981 and 1982, however, coastwise traffic on this portion of the GIWW increased considerably to 1,644,000 tons in 1981 and to 1,090,000 tons in 1982. Principle commodities shipped across the bay during these two years included crude petroleum, phosphate rock, sodium hydroxide, gasoline, and distillate and residual fuel oils.

TABLE 8

MAJOR COMMODITIES MOVED ON THE GIWW
BETWEEN
APALACHEE BAY AND PANAMA CITY
(1000's Tons)

	1971	1972	1973	1974	1975	1976
Gasoline	493	512	503	434	394	419
Residual Fuel Oil	438	421	398	311	312	309
Crude Petroleum Products	179	147	176	171	176	268
Asphalt, Tar and Pitches	157	96	87	64	94	126
Basic Chemical Products	80	77	91	68	58	72
Sodium Hydroxide	72	99	133	204	140	200
Fertilizers	132	235	94	95	104	160
Jet Fuel	52	69	75	102	88	113
Distillate Fuel Oil	82	87	87	96	72	86
Phosphate Rock	39	42	40	42	47	51
Grains (Corn, Oats, Wheat, Soybeans)	40	30	6	11	19	79
TOTAL	2084	2149	2010	1864	1702	2098

	1977	1978	1979	1980	1981	1982
Gasoline	490	856	627	426	374	417
Residual Fuel Oil	362	232	253	373	290	187
Crude Petroleum Products	285	246	550	618	272	1
Asphalt, Tar and Pitches	110	102	99	66	28	82
Basic Chemical Products	73	45	67	65	100	58
Sodium Hydroxide	211	252	242	224	182	129
Fertilizers	251	179	167	206	165	189
Jet Fuel	102	166	189	138	150	34
Distillate Fuel Oil	203	240	165	104	137	158
Phosphate Rock	130	574	291	112	153	172
Grains (Corn, Oats, Wheat, Soybeans)	103	68	74	57	78	77
TOTAL	2635	3194	3000	2617	2247	1680

Source: U.S. Army Corps of Engineers, Waterborne Commerce of the U.S.

B. Two Mile Channel

The Two Mile Channel is a 6 x 100 foot channel which extends from the GIWW and runs parallel to the shore west of Apalachicola. Associated with the project is a 6 x 100 foot connecting channel to the bay and a breakwater. Figure 17 shows the location of the Two Mile Channel and Breakwater.

The Two Mile Channel was authorized in 1963, and constructed in 1964 to provide access for oyster boats to the open bay and the oyster bars. Originally the Two Mile Channel paralleled the shore in front of the access channel to the bay and did not connect with the GIWW channel. However, in 1966 the City of Apalachicola adopted a resolution requesting the COE to study the feasibility of extending the Two Mile Channel to connect with the GIWW. And, in 1970 the Franklin County Board of County Commissioners passed a resolution requesting the COE to construct a breakwater to protect shore installations and vessels. The COE released a study in 1971 which recommended the extension of the Two Mile Channel along the shoreline until it intersected with the GIWW and the construction of a breakwater along the seaward side of the existing Two Mile Channel.

In 1976 the Two Mile Extension and Breakwater were constructed. The breakwater was constructed of the material dredged out of the channel extension and has a top elevation of 7.0 feet above mean low water. To prevent silting of nearby oyster bars, dikes were constructed to confine the runoff. These dikes also served as the outer toe of the main breakwater. The 1.8 mile long breakwater consist of two islands extending 1000 feet along the approach channel. The rationale behind constructing the extension and breakwater was to provide an all-weather safe route to the oyster beds, to provide a shorter route between oyster houses in Apalachicola and oyster beds in the western section of the bay, to provide a shorter route to the Department of Natural Resources for their oyster bed planting program, and to protect the shoreline.

In conjunction with the construction of the breakwater at Two Mile, the COE constructed a marsh on the western breakwater island (Site 6). The marsh was constructed as part of the COE's Dredged Material Research Program and was designed to test the feasibility of propagating selected marsh plants on fine-grained dredged material placed in saline intertidal environments (Kruzynski, et al., 1978). Studies were also conducted to determine the optimum spacing intervals for planting the selected species.

Table 9 shows the dredging history for the Two Mile Channel. Figure 20 shows the location of the disposal sites for the Two Mile Channel. As discussed earlier, no dredging has occurred in the Two Mile Channel since 1978 because of permitting problems. A review of the COE Report of Channel Conditions indicates there has been shoaling problems in the channel since 1979. It is estimated by the COE that the Two Mile Channel will require 100,000 cubic yards dredged from the channel every 18 months, and an additional 75,000 cubic yards dredged from the extension channel every five years if it is to be maintained as authorized (COE, 1982).

Dredged material from the Two Mile Channel is proposed to be placed upon the partially diked disposal islands (Sites 5 and 6) and upon the open-water Sites 1-4 adjacent to the north-south leg

TABLE 9

DREDGING AND DISPOSAL HISTORY
OF TWO MILE CHANNEL

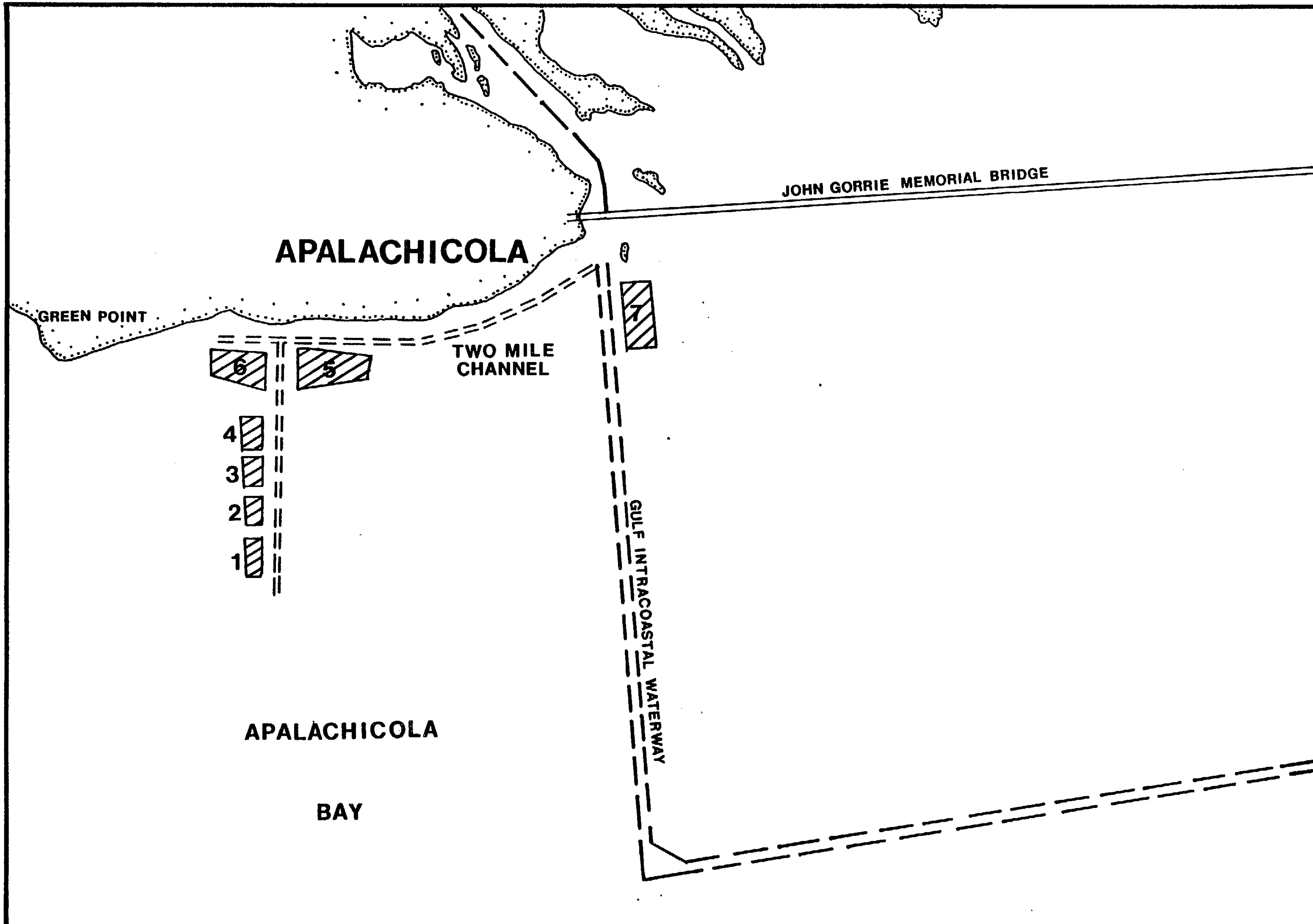
Year(1)	Total Quantity Dredged (cubic yds.)	Disposal Site	Quantity (cubic yds.)
1964	408,558		N/A (2)
1970	181,475	1	22,610
		2	19,780
		3	44,865
		4	63,396
		5	30,822
1974	261,150	2	11,005
		3	58,683
		4	49,701
		5	71,627
		6	70,494
1976	82,800	8	82,800
1976	369,000	7	200,000
		8	169,000
1978	275,000	1	N/A
		2	N/A
		3	N/A
		4	N/A
		8	N/A

Sources: Department of the Army (1965), Peterson (personal communication), COE daily dredge records.

(1) If year not listed then no dredging occured.
(2) N/A means not available.

Figure 20

DREDGED MATERIAL DISPOSAL SITES FOR TWO MILE CHANNEL



SOURCE: C.O.E., 1982

of the channel. The authorized disposal sites associated with the islands (sites 5 and 6) cover roughly seven acres each, and the open-water disposal sites (1,2,3, and 4) are 29 acres each, for a total of 130 acres authorized for dredged material disposal. The choice of the appropriate disposal site used in a specific dredging event depends upon dredging location and the condition of the proposed disposal site. Dredged material from the extension to the GIWW is proposed to be placed on the eastern disposal island (Site 5) for the western half of the channel, and on an open-water disposal area east of the GIWW (Site 7) for the eastern half of the channel.

Disposal Sites 1,2,3,4, and 7 are expected to last the life of the project because current patterns in this area and wave energy are expected to shift bottom material out of the site boundaries over time, making room for subsequent disposal volumes. Disposal Sites 5 and 6 are also expected to last the life of the project since erosion of the islands is expected to offset the material placed upon them. Dredged material placed upon the breakwater will be placed on the southern edge of the breakwater to protect established marsh vegetation (COE, 1982).

C. Eastpoint Channel

The Eastpoint Channel is a 6 x 100 foot channel which parallels the shore of Eastpoint, Florida. The channel is 6000 feet long with a connecting channel to St. George Sound. In 1983 a 5000 foot long breakwater was constructed on the bay side of the channel to protect the channel and shoreline structures.

The Eastpoint Channel was authorized by the River and Harbor Act of 1946 and justified by the fact that local commercial fishermen had to either unload their vessels into small skiffs or go wading to get their catch ashore because of the natural shallowness of this area. Local interests requested a 9 x 100 foot channel, but the COE felt a 6 x 100 foot channel would suffice (U.S. House of Representatives, 1951). In 1954, dredging of the channel at Eastpoint was completed by local interests who were later reimbursed by the federal government (COE, 1978). Since strong southerly winds generate heavy wave action in St. George Sound and regularly caused considerable damage to seafood houses and boats, a breakwater was constructed at Eastpoint in 1983 (COE, 1983a).

Table 10 shows the dredging and disposal history for the Eastpoint Channel since 1970. Figure 21 shows the location of the disposal sites for the Eastpoint Channel. No dredging has occurred in the Eastpoint Channel since 1978, although the COE Report of Channel Conditions again shows that there have been shoaling problems in the channel. It has been estimated by the COE that 50,000 cubic yards of material would have to be dredged every one and a half years to maintain the authorized channel (COE, 1982).

The COE has proposed to place dredged material from the Eastpoint Channel either in two open-water sites adjacent to the channel or on a beach nourishment site adjacent to Highway 98.

TABLE 10

DREDGING AND DISPOSAL HISTORY
OF EASTPOINT CHANNEL

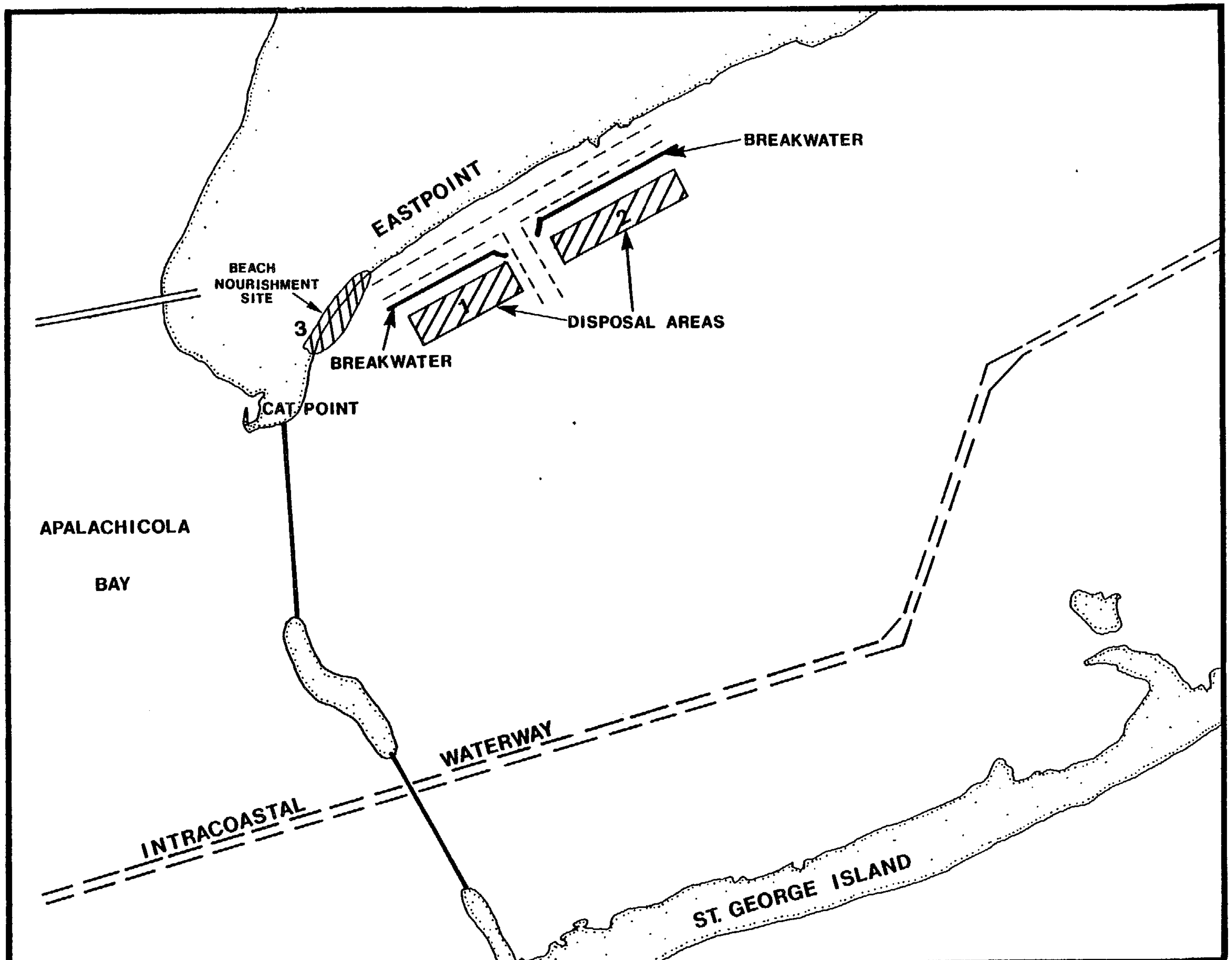
Year(1)	Quantity (cubic Yds.)	Disposal Site
1954	N/A	N/A (2)
1960	67,844	N/A
1964	33,452	N/A
1969	70,228	N/A
1971	49,500	1,2
1976	54,900	2
1977	22,500	2
1978	249,000	1,2

Sources: Department of Army (1960), Department of Army (1964), Department of Army (1969), Peterson (personal communication), COE daily dredge logs.

(1) If year not listed, then no dredging occurred.
(2) N/A means not available.

Figure 21

EASTPOINT CHANNEL DISPOSAL SITES



SOURCE: COE, 1982

The open-water sites total approximately 165 acres. Since these areas are shallow, islands will be created by disposal activity. The beach nourishment site is approximately 4.5 acres and may be used in lieu of or in conjunction with the open-water sites (COE, 1982).

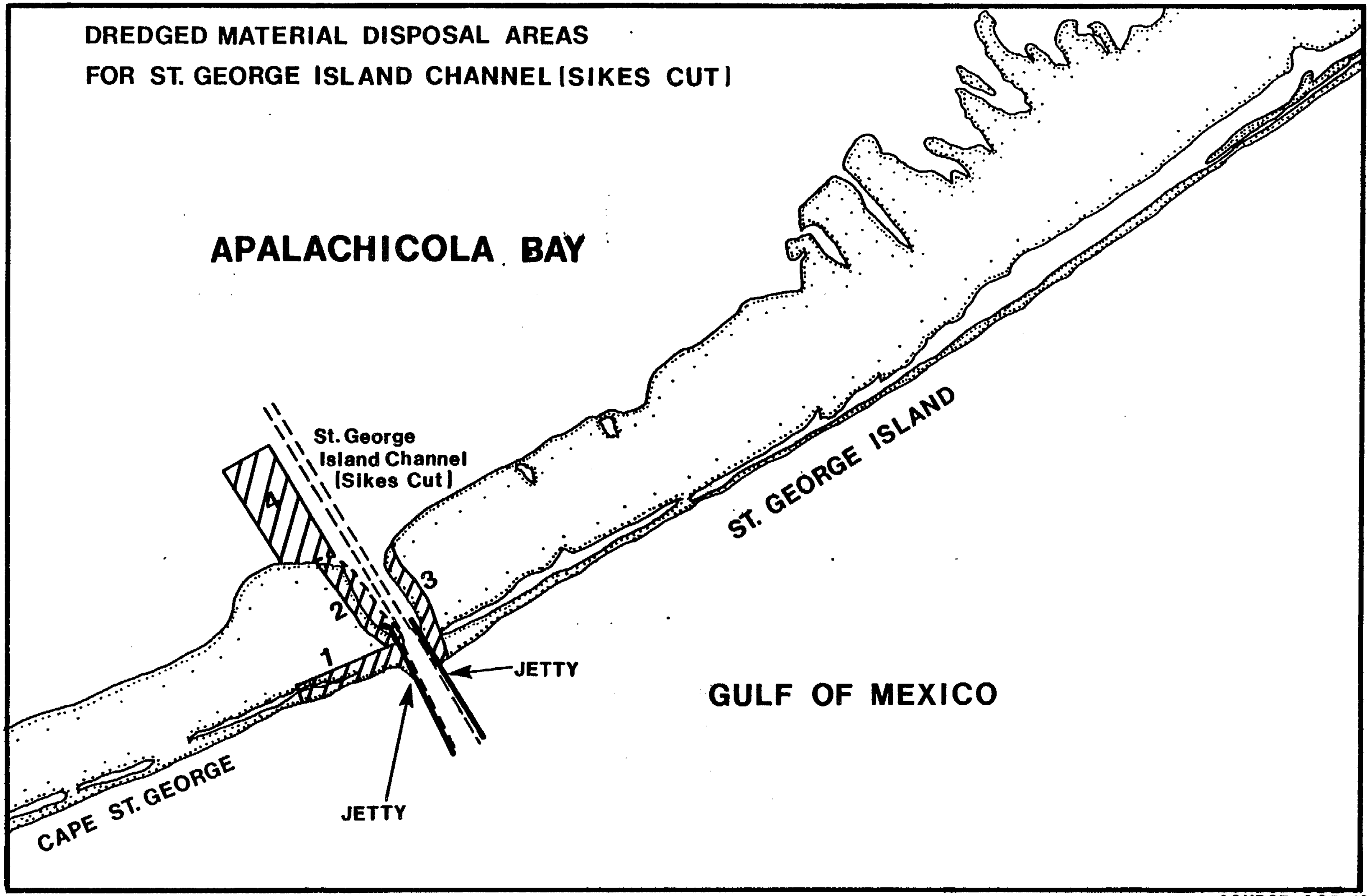
Disposal Areas 1 and 2 are expected to last the life of the project because the sediment is expected to be moved out of the sites due to wave energy and current patterns, providing space for more disposal material. Since concerns have been expressed that material from the disposal sites will ultimately settle on oyster bars southwest of the disposal sites (i.e., Cat Point), the breakwater permit required an extensive monitoring program for disposal material associated with breakwater construction and disposal operations from the Eastpoint Channel.

D. St. George Island Channel (Sikes Cut)

The St. George Island Channel, also referred to as Sikes Cut, is a 10' x 100' channel extending from a 10 foot depth in Apalachicola Bay, across St. George Island, to within 300 feet of the gulf shore. From this point the channel increases uniformly in width to 200 feet at the gulf shore out to a 10 foot depth in the Gulf of Mexico. Twin jetties extend gulfward from the dune line to the outer edge of the channel (COE, 1983). Figure 22 is a diagram of the authorized project and disposal sites.

According to Zeh (1979) construction of the channel was first proposed in 1937 when local shrimp and fishing interests requested

Figure 22



SOURCE: COE, 1982

that a 15' by 100' channel be dredged through a former natural opening in St. George called New Inlet to reduce the travel time to gulf fishing grounds. This request was rejected by the COE, but a subsequent request in 1939 to construct a 10' x 100' channel 2.5 miles east of New Inlet was supported, and in 1952 this channel was authorized. Because of delays in project authorization and construction, the channel was actually cut by local interests according to COE specifications. Since the mouth proved to be unstable and shifted seasonally, the COE constructed two jetties on the gulf side and assumed maintenance of the channel in 1957.

In 1970 the University of Florida submitted a report to the U.S. Army Corps of Engineers, Mobile District, proposing that the jetty system be extended back through the channel because erosion of the channel walls was contributing a significant percentage of the material dredged from the channel (U. of Florida, 1970). The COE, however, rejected this proposal. Because of the erosion of private property on the eastern bank of the land cut, extending the jetties on either one or both sides of the cut is again being considered.

Table 11 lists the dredging history of Sikes Cut. From 1958 to 1970 the principal areas needing dredging were directly offshore, in the center of the cut, and between 1000 to 2000 feet north of the bay side of the cut (U. of Florida, 1970). These are roughly the same areas still requiring maintenance dredging (Peterson, personal communication). Shoaling in the cut is caused by erosion of land from the sides of the cut and to a limited

TABLE 11

DREDGING AND DISPOSAL HISTORY
OF ST. GEORGE ISLAND CHANNEL

Year(1)	Quantity Dredged (cubic yds.)	Disposal Site
1958	60,188	N/A (2)
1959	29,435	N/A
1960	25,998	N/A
1961	35,312	N/A
1962	24,321	N/A
1963	32,973	N/A
1964	89,164	N/A
1965	58,754	N/A
1966	115,181	N/A
1967	10,592	N/A
1968	38,544	N/A
1969	21,735	N/A
1970	21,785	4
1971	14,639	3
	56,980	4
1972	50,000	3
1974	18,241	2
	3,022	4
1975	54,995	1
1976	5,246	3
	22,400	4
1978	134,900	
1984	17,000	2
	41,500	3
1985	45,600	1
	800	2
	10,900	3
1986	63,300	1
	18,900	3

Sources: Zeh (1979) 1958-1969, COE dredging records (1970-1982), Peterson (personal communication).
(1) If year not listed, then no dredging occurred.
(2) N/A means not available.

extent from material moving into the cut, whereas shoaling in the gulf is caused by movement of littoral material (Peterson, personal communication). Shoaling in the bay is caused by movement of bottom material during periods of rough water in the bay.

As discussed earlier, no dredging occurred between 1977 and 1983 because of problems associated with permitting. COE Report of Channel Conditions indicated that shoaling problems occurred in the cut during this period. The cut was dredged in 1985 because of shoaling caused by Hurricane Elena, and again in early 1986 because of shoaling from Hurricane Kate.

The channel was cut in a south-southeastern direction, which over the course of the year is also the direction of prevailing wind and swell. It has been suggested (U. of Florida, 1970) that if the channel had been cut with its center line facing south, maintenance needs on the channel would have been reduced. It is estimated that in the future an average of about 50,000 cubic yards will have to be dredged annually to maintain the project (COE, 1982).

Disposal sites at the cut are located in open-water areas within the bay and upland areas adjacent to the channel and on the gulf beaches (See Figure 20). Because of erosion caused by tidal and wave actions, disposal Sites 1,2, and 3 are expected to last the life of the project. Disposal Site 4 is also expected to last the life of the project because bottom sediments will shift away from the site, and it can then be used again (COE, 1982). The specific site used for disposal depends upon the location of dredging and the amount of erosion at the beach renourishment site. The size of the disposal sites are approximately 9 acres at Site 1, 2 acres at Site 2, 4 acres at Site 3, and 41 acres at Site 4.

In 1975 the Board of County Commissioners of Franklin County requested a federal study to have Sikes Cut dredged to 12 feet to allow larger vessels access to the gulf. This proposal was rejected after a feasibility study by the Corps of Engineers determined that the project cost exceeded the limitations of funding for the small projects program under which funds were sought, and that the requested changes would need to be accomplished under the authority of congressional resolution (COE, 1977).

Because of: 1) long-standing questions regarding the impact of the cut on the oyster resources of the bay, 2) considerations being given to stabilizing the cut, and 3) the COE's proceeding with obtaining a permit for the bay projects, a study has been initiated to assess the range of impacts associated with the maintenance and existence of the cut. This study should be completed in Spring 1986 and is discussed later in this report. It is conceivable that if the study shows sufficient impacts associated with the cut, either maintenance of the cut will be abandoned or the cut will be physically closed. In the event this occurs, active maintenance of the access channels through West Pass (i.e., the Outer Bar Channel and Link Channel) could occur (see Section IV,F for a discussion of those channels).

E. Scipio Creek Channel

The Scipio Creek Channel is a 9 x 80 foot channel extending from the Apalachicola River up Scipio Creek to a 200 x 880 foot boat basin just north of the City of Apalachicola. The channel and boat basin were built to provide a haven of refuge during storms for the fishing vessels operating in the bay (U.S. House of Representatives, 1951). The dredging of the Scipio Creek Channel and Boat Basin was recommended by the COE in 1951, authorized in 1954 and done in 1957. The boat basin is presently used mainly as a mooring area for the smaller shrimping boats which constitute the bay shrimp fleet, while larger shrimp boats moor along the western edge of the access channel.

When the access channel and basin were initially dredged, 40,803 cubic yards were removed from the access channel and 75,599 from the basin (Department of Army, 1957). No dredging has been done since. The COE have recently proposed maintenance dredging 25,000 cubic yards from the channel and estimate dredging will not be necessary for another twenty years (COE, 1982).

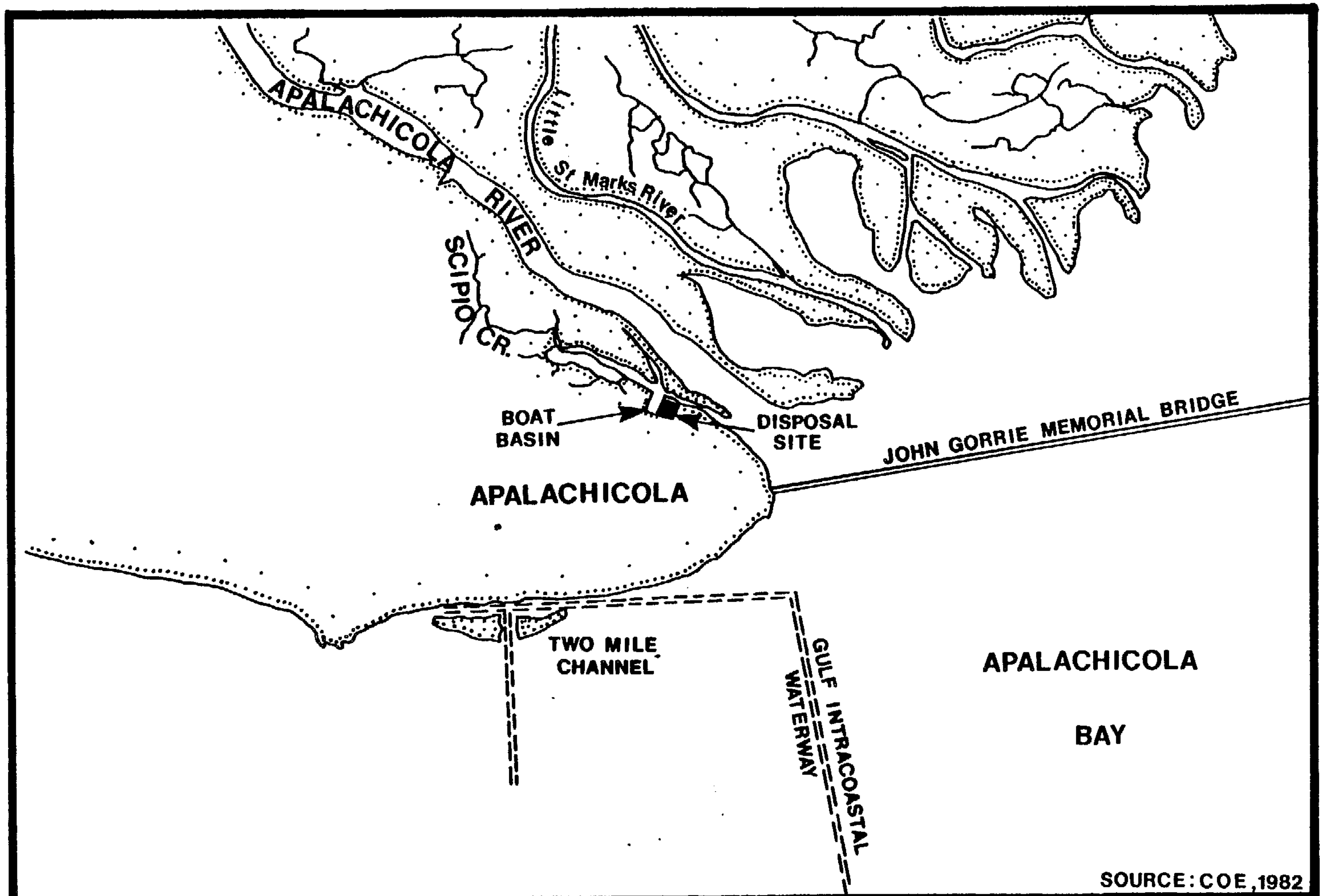
The COE has proposed a three acre upland diked disposal area, adjacent to the turning basin with runoff from the site returning to Scipio Creek (see Figure 23).

F. Other Projects

In addition to the five currently active navigation projects in Apalachicola Bay, there are a number of projects not presently

Figure 23

DREDGED MATERIAL DISPOSAL AREAS FOR THE SCIPIO CREEK CHANNEL



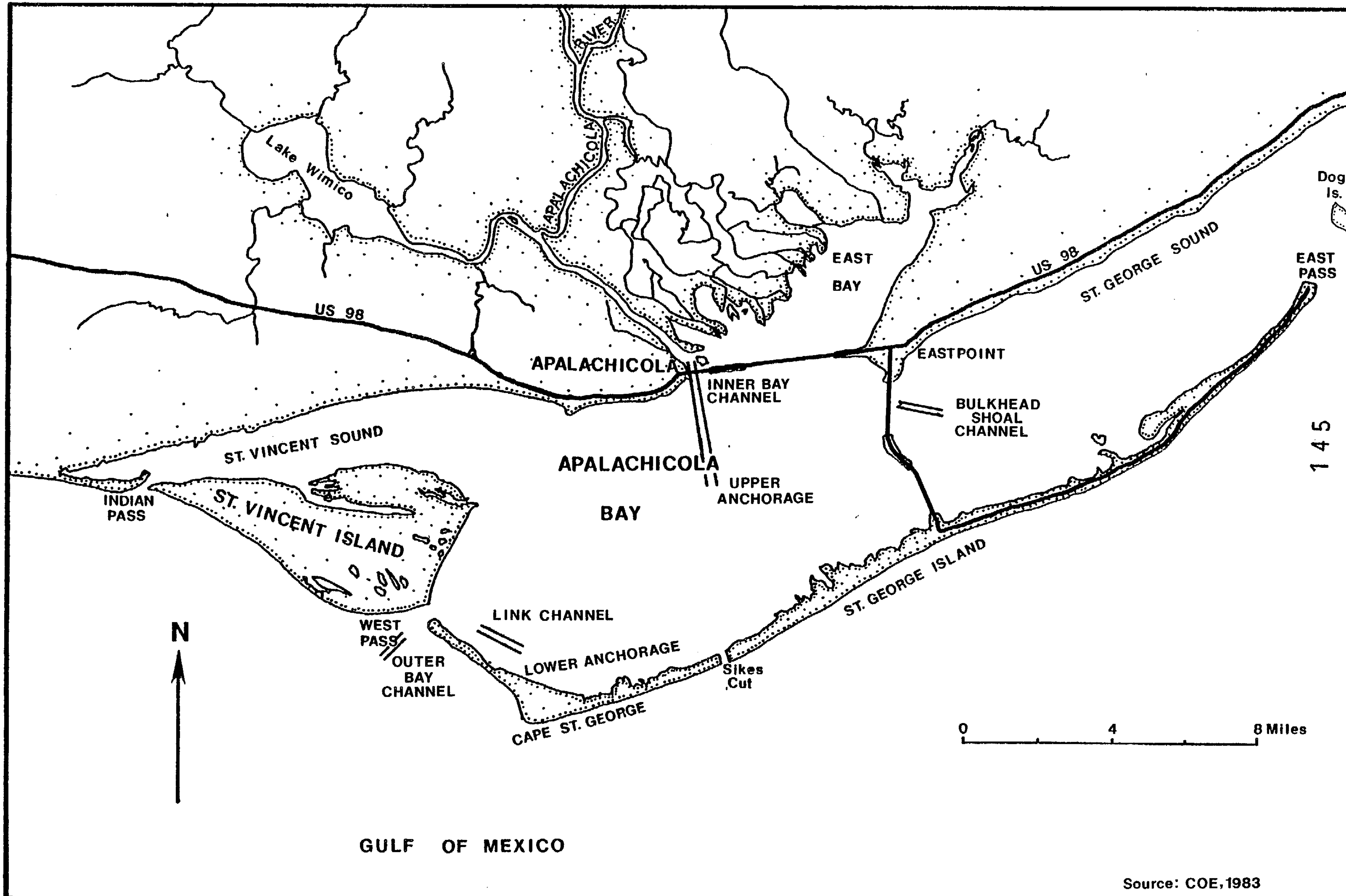
being maintained: Bulkhead Shoals Channel, Link Channel, and a channel through the Outer Bar at West Pass (see Figure 24). An additional earlier project, the Inner Bar Channel, has been incorporated into the GIWW.

The Inner Bar Channel originally provided a channel entrance from the Apalachicola River to the anchorage areas in Apalachicola Bay. The COE's plan of improvment was to dredge a straight channel through the bar at the mouth of the river to 11 x 100 feet and to increase the channel dimensions to 11 x 200 feet if warranted. The channel was to be roughly 6000 feet long (Chief of Engineers, 1882). In 1907 the project was amended to provide a 10 x 100 foot channel at low water through the mouth of the Apalachicola River and it was suggested that a bulkhead be constructed adjacent to the channel to reduce its silting (Chief of Engineers, 1907). In 1908, a 6900 foot long timber bulkhead was constructed east of the channel. By 1916 the bulkhead had deteriorated due to damage by storms and marine organisms (Chief of Engineers, 1917) and was never restored. When the GIWW was authorized in 1939, the Inner Bar Channel was incorporated into the GIWW Channel. From 1882 to 1939 the Inner Bar Channel was regularly dredged and the maintenance of this channel was believed to have increased the commerce at the Port of Apalachicola, and resulted in a substantial reduction in freight rates to and from Apalachicola (Chief of Engineers, 1917).

In 1891 it was recommended that a 9 x 100 foot channel be cut through Bulkhead Shoal because it was the most serious obstruction to commerce (i.e., exportation of lumber) via East Pass (Chief of Engineers, 1891). The Bulkhead Shoal Channel was initially cut in

Figure 24

OTHER BAY PROJECTS



1892. This channel, which connects Apalachicola Bay to St. George Sound, has only been maintenance dredged twice since its construction, once in 1928 and again in 1936.

The Outer Bar Channel at West Pass and Link Channel were constructed to provide access from the open gulf waters through West Pass to Lower Anchorage. In 1900, the Outer Bar Channel at West Pass was first dredged to 17 x 150 foot dimensions, but after it shoaled, it was relocated and redredged in 1907 to 18 x 150 foot dimensions as authorized by Congress in 1907 (Chief of Engineers, 1907). The length of Link Channel, first dredged in 1905, was 5000 feet, and the length of Outer Bar Channel was 5280 feet.

After periodic maintenance the Link Channel and Outer Bar Channel were recommended for abandonment in 1917 because they provided no commercial advantage (Chief of Engineers, 1917). Although this recommendation was continued through 1925 (Chief of Engineers, 1925), the project was never formally abandoned. In 1936 and 1948 the Outer Bar Channel was maintenance dredged. As discussed earlier, it is conceivable that if the ongoing evaluation of Sikes Cut determines that continued maintenance of the cut is ill-advised, active maintenance of the Outer Bar Channel and Link Channel may be reinstituted.

The Rivers and Harbors Act of 1910 called for a preliminary examination of Apalachicola Bay and St. George Sound to determine the best location for a deep water harbor with entrance from the Gulf of Mexico, by way of East Pass, West Pass, New Inlet or an artificial cut across St. George Island (Chief of Engineers, 1911). No record of follow-up on this examination was found.

V. IMPACTS OF DREDGING AND DISPOSAL

Dredging and disposal activities can have a variety of impacts on estuarine and coastal ecosystems. Effects can range from obvious ones such as habitat burial by the disposal material, to more subtle ones such as alterations of circulation pattern caused by bathymetric changes. This section of the report reviews dredging and disposal impacts on estuarine systems in general, and on the Apalachicola Bay system in particular. Also included are reviews of specific dredge-related studies and impact assessments. A summary of the findings of these studies concludes the section.

A. General Impacts

As part of the 1970 River and Harbor Act (Public Law 91-611), Congress authorized the COE to initiate and conduct a series of studies on the impacts of dredging and disposal. Physical, chemical, and biological investigations of the impacts of dredging and disposal practices have been carried out in such a manner as to evaluate different dredging techniques, different sediment types (coarse to fine, clean to contaminated), and different disposal environments (freshwater, estuarine, and open ocean). This work, known as the Dredged Material Research Program (DMRP), was prepared under the guidance of the COE Waterways Experiment Station at Vicksburg and was conducted through interagency agreements or through contracts with universities and private concerns. This extensive body of work includes Environmental Laboratory (1978), Gambrell, et al. (1978), Hirsch, et al. (1978), and Stern and Stickle (1978), and is summarized in Olsen (1982), as well as two publications by the U.S. Fish and Wildlife Service, Morton (1977) and Allen and Hardy (1980). Information from the DMRP was used to provide an overview of the impacts of dredging and disposal on the aquatic and terrestrial environment.

The above literature indicates that the disposal phase of dredging operations usually has far greater and more significant impacts on environmental variables than does dredging itself. In many estuarine systems, including Apalachicola Bay, open-water disposal is the method most often used. The impacts of a specific dredging event depend on the localized hydrographic and sediment characteristics, and therefore, the management of dredged material must be determined on a site-by-site basis. In this section, the impacts of open-water disposal have been divided into three categories: physical, chemical, and biological. Although discussed separately, these impacts are interrelated. Additionally, impacts of other disposal methods (upland, wetland, beach, island-creation and open ocean) are discussed.

1. Open-Water Disposal

a. Physical Impacts

Dredging and disposal activities constitute a physical process of removal, transport, and deposition of sediment that differs from the natural process in being much more concentrated in time and space (Morton, 1977). Nevertheless, several studies have indicated that sediment remobilization during dredging may be similar to natural resuspension (Tramontano and Bohlen, 1984). However, unlike natural resuspension, a dredge mobilizes both fine and coarse material and discharges them into the water column. The coarser material subsequently settles rapidly near the point of discharge, while the finer sediments remain in suspension longer and move away from the discharge point. The most visible impact at the dredge site and the disposal area is increased turbidity and suspended solids, with a corresponding reduction of light penetration. The higher than ambient turbidities generated by dredging and disposal activities generally form plumes which extend outside the disposal area. Although they are short-lived, these plumes can extend over large areas of an estuary. Only about 1% of the total mass of solids discharged is incorporated into the initial plume (Schubel, et al., 1978). The rest of the solids (99%) settle out rapidly, with the finer particles becoming incorporated into "fluid mud." The effects of fluid mud on the environment are described in a later section. The severity of turbidity effects are generally related to the degree of mixing in a water body (Allen and Hardy, 1980). The biota in well mixed, dynamic systems which periodically experience natural increases in turbidity, like Apalachicola Bay, are less affected by high turbidity than in systems which do not experience significant natural fluctuations in turbidity levels.

Dredging and disposal activities also physically impact bottom topography by creating channels and building disposal mounds. Physical modification of the bottom can affect the circulation pattern of an area changing salinity, current velocity, erosion and depositional patterns, and flushing times. These, in turn, can alter nutrient and dissolved oxygen concentrations, temperature regimes, and the biological components of the system. Changes in circulation patterns caused by dredging activities may not necessarily be harmful. However, predicting what impacts may occur from circulation modifications is difficult.

The substrate itself can be physically changed by dredging and disposal activities. Newly resettled sediments have been observed to have a coarser median grain size than that measured prior to dredging because the fine silt and clay fraction has been resuspended. This change in median grain size affects porosity, which has an important bearing on the flux of chemicals and contaminants across the sediment-water interface, the distribution of benthic organisms, and later redistribution of dredged sediments after disposal (Morton, 1977).

When evaluating the physical impacts of dredge and disposal activities, the fate of the material which is disposed of in open water (undiked) disposal areas needs to be examined. As mentioned previously, up to 99% of the total solids discharged settle rapidly to the bottom. Since increasing salinity enhances flocculation, the percentage of material resettled (i.e., solids and finer materials) is related to salinity (Meade, 1972). The mineralogy of the suspended sediments is also a major factor affecting flocculation. Increased flocculation may help in the formation of "fluid mud," a highly concentrated layer of suspended material. This material is denser than water, moves in a more or less unified body of material, and is affected by gravity, which means it is also affected by the slope of the bottom topography (Schubel, et al., 1978). Therefore, there is no guarantee that the disposal material will stay in the disposal area, even on a short-term basis.

The long-term fate of dredged materials is also uncertain. Wind generated waves and tidal currents can resuspend the deposited sediments and are principally responsible for their lateral transport. Studies conducted in Chesapeake Bay (Chesapeake Biological Laboratory, 1970) indicated that disposal material covered an area at least 5 times greater than the disposal site 150 days after the completion of disposal operations. Approximately 12% of the disposal material had left the disposal site during this time. A study in Galveston Bay determined that 40% of the disposal material had left the disposal site immediately after being deposited, and within six months the spoil covered an area three times larger than the original area (Bassi and Basco, 1974).

b. Chemical Impacts

Dredge and disposal activities can impact the chemical constituents in the water column and sediment layer. Because of the chemical properties of seawater, the flocculation and precipitation of materials from the water column is enhanced in saline environments, and estuarine sediments generally act as a sink for contaminants. As sediments are dredged and disposed, the potential for remobilization of chemical compounds and organics associated with the deeper sediment layers increases. These chemical constituents are usually in a reduced state due to the anaerobic environment in subsurface sediments, and are not in equilibrium with the overlying water, as are the surface deposits. Most of the chemical changes occurring are related to the release, resuspension, and deposition of organic matter, nutrients, and chemical contaminants such as heavy metals, pesticides, PCB's, and other industry-related compounds.

Change in the dissolved oxygen (DO) concentration of the water surrounding dredge and disposal sites is probably the first chemically related impact noticeable. DO concentrations have an important effect on the form, solubility, mobility, and ultimate destination of the chemical constituents of the disposal material. In most instances there appears to be a temporary reduction in DO concentration in the waters overlying both the dredge and disposal sites. Morton (1977) lists several factors which may influence the effect of dredging and disposal on local DO concentrations: 1) the stimulation or inhibition of primary production, 2) changes in physical arrangement of the sediment, 3) the redox potential of the sediment, 4) the magnitude of the organic fraction in the sediment, 5) chemical composition of the sediment, 6) how the sediments are handled during dredging and disposal, and 7) the degree of flushing that occurs at the dredging and disposal sites. Since habitats vary considerably, the degree of change in DO concentration will be dependent on these variables. Generally, there is an increased oxygen demand caused by the degradation of resuspended organic matter and the oxidation of various reduced compounds from the deeper sediment layers.

There can be a signficant release of nutrients when bottom sediments are resuspended in the water column. In general nutrients, particularly ammonia, have the potential to present the greatest environmental problems during dredging (Ryan, et al, in prep). During dredging the release of sediment-bound nitrogen and carbon compounds has a potential to impact aquatic biota (Ryan, et al., 1984). Remobilization of sediments enriched in organic matter can significantly elevate the BOD and depress the concentrations of oxygen in the water column. However, in a well-mixed, dynamic estuary such as Apalachicola Bay, the potential for detrimental impacts is reduced. The relative concentrations of nutrients, organic material, and chemical contaminants in the sediment are generally related to the percentage of fine silts and clays present. These compounds, through sorption and flocculation settle out in bays and estuaries. The chemical impacts of the disposal material on the environment, and the physiochemical state of the contaminants in the disposal material, significantly affect the release of chemical contaminants and make prediction of potential releases difficult and complex.

The resuspension of toxic contaminants probably poses the greatest danger to the environmental health of an estuary. These contaminants include heavy metals, pesticides, petroleum hydrocarbons, and chlorinated hydrocarbons (e.g. PCB's, etc.), which accumulate in the sediments shortly after being introduced into estuarine waters. Many of these compounds degrade very slowly and become concentrated in the sediments in relation to the overlying water. During dredging and disposal activities contaminants are resuspended into the water column. There is disagreement among researchers as to the potential impacts from these pollutants. Most agree that the majority of these compounds are tightly bound to clay particles and their release back into the water column is limited, with most contaminants settling back to the bottom. Nevertheless, these contaminants still pose a long-term potential hazard to an ecosystem. The effect of these pollutants are still being studied, and may range from acute toxicity to little or no effect. Synergistic and long-term effects are still being studied and the potential for adverse impacts is significant. The reader is urged to consult Morton (1977), Allen and Hardy (1980), and Olsen (1982) for a review of potential impacts concerning the transfer of contaminants through dredge and disposal activities. The limited data available have not confirmed that contaminants are problem in Apalachicola Bay.

c. Biological Impacts

The physical and chemical aspects of dredging and disposal discussed above affect estuarine organisms and their interaction with the environment. Assessment of dredging impacts on biota is difficult because estuaries are dynamic and diverse systems, and estuarine organisms exhibit great variation in their life histories, basic requirements, spatial distribution, and seasonal abundances (Morton, 1977). Sampling designs, with their practical constraints, are often not capable of accurately revealing effects of dredging on estuarine organisms under such variable conditions.

Many toxic and physiological impacts found in laboratory experiments may or may not accurately reflect real impacts occurring in the field. Seasonal variations in biological communities is of special concern in relation to dredging. Sensitive reproductive seasons should be avoided.

The community most affected by dredge and disposal activities is the benthic community. It is made up of a wide range of species that differ greatly in habitat, mode of feeding, and tolerance of environmental stress (Taylor, et al., 1970; Gordon, et al., 1972). An obvious impact on the benthic community caused by dredging is the destruction of organisms in the path of the dredge itself. Maintenance dredging involves only a small area of estuarine bottom, while the disposal of the dredged material generally involves a larger area and impacts more organisms. direct burial probably impacts more of the benthic community than any other factor. Many sessile organisms are killed outright, although the degree of mortality is related to the composition of dredged material and depth of burial. Animals that are generally more mobile, such as polychaetes and some bivalves, have a greater chance of surviving by migrating up through the deposited material. It is difficult for a shelled organism such as a clam to migrate up through loose muddy material, such as fluid mud, since it offers little support for their body weight (Mauer, et al., 1978). Sheer weight of material is also a factor in mortality rates. For a more detailed review see Hirsch, et al. (1978) and Wright, et al. (1978).

The recovery of an area that has been inundated with dredged material is dependent on the type of material deposited, depth of material deposited, the type of benthic community that was covered, the types and proximity of surrounding benthic communities, the size of the affected area, and the presence of contaminants in the material. The season of deposition also affects recovery time. Some studies (Chesapeake Biological Laboratory, 1970; Slotta, et al., 1973) report full recovery of disposal areas, while others (Gross, 1970; Kaplan, et al., 1974) have found limited recovery and a shift in species composition. Methods of recovery of benthic communities in disposal areas include arrival of new larval forms, horizontal migration from nearby areas, and the vertical migration of the indigenous bottom fauna, although this method is uncommon (Olsen, 1982). In some instances there has been a shift in the type of benthic community that reestablishes an area because the habitat has been changed by the dredging and disposal activities (i.e. water depth, sediment type, circulation pattern) (Morton, 1977). Recovery time, type, and amount are difficult to predict because of seasonal differences in populations of organisms, habitat differences, current differences, and the effects of contaminants.

Other impacts on the benthic community include acute and sublethal effects of contaminants and other physiological effects. Galtsoff (1964) showed that deposits of silt or loose sediments as thin as 1 mm over a hard substrate or shell surface is sufficient to cause failure of setting for oyster and other larvae. In terms of egg development, Loosanoff (1961) demonstrated that silt levels of 250 mg/l will significantly effect the development of oyster eggs. Lunz (1938), Loosanoff and Tommers (1948) and Sherk (1971) studied the effect of suspended solid loads on filter feeding organisms and found that at sufficient concentrations it affected their pumping rate, the efficiency of their filtering mechanism, and the energy needed for maintenance. Specific disorders which have been observed include: abrasion of gill filaments, clogging of gills, impaired respiration, impaired feeding and excretory functions, reduced pumping rates, retarded egg development, and reduced growth and survival of larvae (Morton, 1977). All of these effects can result in a decline in the productivity of the benthic community, which can have significant impacts on higher trophic levels and commercially important species.

The significance of contaminant effects on the benthic community has been studied and debated for years. Many organisms take up pollutants such as heavy metals, pesticides, PCB's, etc., and magnify the concentra- tions substantially beyond that found in the water or sediment. This biological magnification or bioconcentration becomes more significant as these compounds are passed to higher trophic levels. For a more detailed review consult Morton (1977), Hirsch, et al. (1978), or Olsen (1982). The effects of contaminated sediment disposal on benthic organisms can be significant and range from no effect to acute toxicity and death in different organisms depending on the type and concentration of the contaminant. Synergistic effects are also under study.

Other estuarine organisms, such as microbiota, phytoplankton, zooplankton, fish, and aquatic plants, are also affected by dredge and disposal activities. Effects of chemical contaminants on these organisms will not be discussed since they have not been shown to be a problem in Apalachicola Bay. For a literature review of contaminant impacts on these communities consult Morton (1977), Hirsch, et al. (1978), Allen and Hardy (1980), and Olsen (1982).

Fecal coliforms and enteric pathogens including Vibrio species are known to adhere to sediment particles in aquatic and estuarine systems (Grimes, 1975; Hood, et al., 1981, 1983b; Williams, personal communication). In Apalachicola Bay, Vibrio species have been recovered in surface floc, and as far down as six inches into the sediment (Williams, personal communication). These sediment-bound organisms are released to the overlying water when sediment is disturbed and relocated, as in dredging operations or heavy storms. Sands provide natural attachment sites for bacteria and adsorb them loosely; therefore, they may be easily resuspended in a disturbance event (Grimes, 1975). Regulatory agencies and those interested in public health are concerned about bacterial suspension near oyster bars during dredging events, since high levels of bacteria may be ingested and concentrated by the oysters. These levels may then increase during storage or processing once harvested (Hood, et al., 1983a).

Phytoplankton productivity and aquatic plants can be affected by dredging and disposal activities in three ways. First, increased turbidity reduces light penetration which reduces productivity and the depth of the photosynthetic zone. Prolonged decreased light penetration due to turbidity can result in a die-off of rooted aquatic vegetation with resulting erosion and dissolved oxygen effects. Most seagrasses require a minimum of 10 to 15 percent of surface light levels for survival (Bittaker, personal communication). Small reductions of already low light levels could result in the loss of aquatic plants. Second, large quantities of nutrients are usually released from the sediment during disposal activites. Such nutrient enrichment can lead to a shift in species composition to less desirable species that could disrupt food web interactions in the system (Morton, 1977),. In dynamic estuaries like Apalachicola Bay the potential for this impact is reduced, although some areas of the bay with less well-mixed waters could be affected. Third, aquatic plants can be lost due to direct burial under dredged material or the movement of fluid mud onto vegetative communities.

Impacts on zooplankton are difficult to observe because of their patchy distribution and seasonal variation. Sullivan and Hancock (1973), and Sherk, et al. (1974) observed reduced feeding by zooplankton in the presence of high suspended sediment concentrations in the laboratory. Most researchers have been unable to detect any evidence of impacts on zooplankton caused by dredge and disposal activities.

Fish populations are also patchy and difficult to quantify. Their ability to avoid dredge and disposal sites also makes it difficult to detect dredging impacts upon them. Suspended sediment has been shown to clog fish gills, reducing their oxygen consumption, but little mortality from dredging has been observed. Demersal eggs may be covered and destroyed by disposal, or a change in the habitat may reduce the reproductive capacity of some species. Such habitat alterations by dredge and disposal activities could prove detrimental to some species and beneficial to others. These changes are hard to quantify and difficult to predict. Areas where fish occur in large numbers, such as spawning grounds, nursery areas, and feeding areas, should always be protected.

The above research indicates a broad range of possible impacts on biota in estuarine systems. Impacts can vary from one system to another. This emphasizes the need to study systems individually before disturbing natural processes in a way which could irrevocably alter the productivity of the estuary.

2. Other Disposal Techniques

Alternative techniques which have been used elsewhere instead of open- water disposal include wetland disposal, upland disposal, beach disposal, and island-creation disposal, and continental shelf disposal. Because of the distance to the Gulf of Mexico and the subsequent economic infeasibility, deep-ocean disposal will not be discussed. Disposal of dredged material onto wetland areas was once routine and widespread. However, now wetlands are protected by the state and federal government because their habitat value, and disposal of dredged material there is less frequent. In cases where wetland disposal has been the only viable choice, the decision concerning spreading the material thinly over a large section of the wetland or constructing a confined area within the wetland, have to be studied carefully in order to lessen the impact on the system (Allen and Hardy, 1980). In many instances confined disposal sites in wetlands become upland as they are filled, permanently altering the wetland.

Upland disposal is another technique which has been used extensively but less often in populated areas due to the scarcity of cheap land. Confined upland disposal areas are considered one of the few options available for the disposal of contaminated dredge material. Confined (diked) disposal areas can impact fish and wildlife positively or negatively, depending on whether the new habitat is more productive than the habitat that existed previously (Allen and Hardy, 1980). Other concerns from upland disposal include:

1) alteration of existing runoff patterns;
2) the exit of contaminants from the disposal area through the effluent;
3) the potential ingestion of contaminants by fish and wildlife utilizing the new habitat;
4) increased turbidity and sedimentation from dike construction and effluent discharge; and
5) possible proliferation of undesirable animal and plant species in the confinement area (Allen and Hardy, 1980).

If the material disposed of is contaminated, other concerns such as possible groundwater contamination must also be addressed.

Beach disposal has been used in conjunction with beach nourishment projects for the disposal of sandy material. Dredged material with high percentages of silt and clay would not be suitable for such projects. The main impact of beach disposal appears to be increased turbidity for several months as the fine-grained material is worked out of the disposed sediment (Allen and Hardy, 1980).

Dredged material has also been used to construct islands in shallow waters or wetlands in deeper waters. One such project was completed in Apalachicola Bay during the Two Mile Channel construction (Kruczynski, et al., 1978). Impacts associated with this technique include the permanent loss of wetland or water bottom, changes in circulation patterns and associated hydrologic effects, and increased surface runoff (Allen and Hardy, 1980). These impacts do not necessarily have to have a negative effect. Creating an island community with an associated marsh and wetland could increase the habitat value for fish and wildlife. The creation or restoration of seagrass beds would not involve most of these potential negative impacts.

In Texas, an experimental containment pond for mariculture of shrimp was constructed using dredged material from the GIWW near Freeport (Quick, et al., 1978). The experiment was jointly designed and operated by the COE (WES, Vicksburg) and Dow Chemical Company. The rearing of shrimp in the diked containment area was highly successful, although economically, it was very costly. For such mariculture to be feasible on a commercial scale by the private sector, additional cost-reducing techniques of spawning and hatching shrimp within the containment area would need to be used (Quick, et al., 1978). If such technology becomes available, this usage of dredged material might be considered in the Apalachicola Bay area.

Continental shelf disposal involves similar impacts on the environment as open water disposal in estuaries, although adverse impacts are generally not as severe because of the greater dilution, mixing, and assimilative capacities involved (Allen and Hardy, 1980). Oceans are nutrient-poor when compared to estuaries and, therefore, the addition of nutrient rich dredge disposal material does not have the potential impacts of nutrient loading as does open-water disposal in estuaries. Before using this disposal technique, quantity and quality of the dredged material should be evaluated thoroughly to minimize impacts and avoid degradation to productive shelf areas.

B. Studies of Impacts on the Apalachicola Bay System

Dredging, disposal, and other man-made alterations of the natural environment have been occurring in the Apalachicola River and Bay system since the early 1800's. Concern about environmental effects of such alterations and their potential impacts on the seafood industry has resulted in some specific investigations in Apalachicola Bay. In the mid 1970's the COE contracted two studies to evaluate the impacts of dredging and disposal on Apalachicola Bay: Water and Air Research, Inc. (WAR) (1975) and Taylor (1978). In addition to these dredging studies, DER contracted with Dr. R.J. Livingston of Florida State University to determine whether his Aquatic Research Group's long-term data base indicated impacts which could be attributed to dredging and disposal practices (Livingston, 1984a). In conjunction with the Dredged Material Research Program conducted by the COE Waterways Experiment Station, Kruczynski, et al. (1978) studied marsh development at the Two Mile disposal island and Schubel, et al. (1978) studied turbidity plumes in the bay. Utilizing existing studies on Apalachicola Bay and other estuarine systems, the COE has prepared several environmental impact statements and environmental assessments of how dredging and disposal might impact the estuary.

A number of monitoring and study efforts were required by permits to assist the DER in evaluating the impacts of dredging and disposal. The permit for dredging Sikes Cut required the COE to conduct a synoptic salinity study to be performed before and after maintenance dredging to determine any salinity changes in the bay caused by the project. The Eastpoint Channel dredging permit required a study of the effects of the breakwater on currents through the development of a model as well as water quality monitoring before and after dredging. The permit for dredging the GIWW required the COE to:

(1) monitor turbidity resulting from open-water disposal;

(2) monitor oyster bars whenever dredging and disposal occurs in the vicinity of a productive bar;

(3) complete development of a mathematical model to simulate hydrodynamic and salinity regimes in the Apalachicola estuary;

(4) conduct a study on fluid mud flow associated with

dredging and disposal in the bay to determine the distance fluid mud migrates from the disposal area;

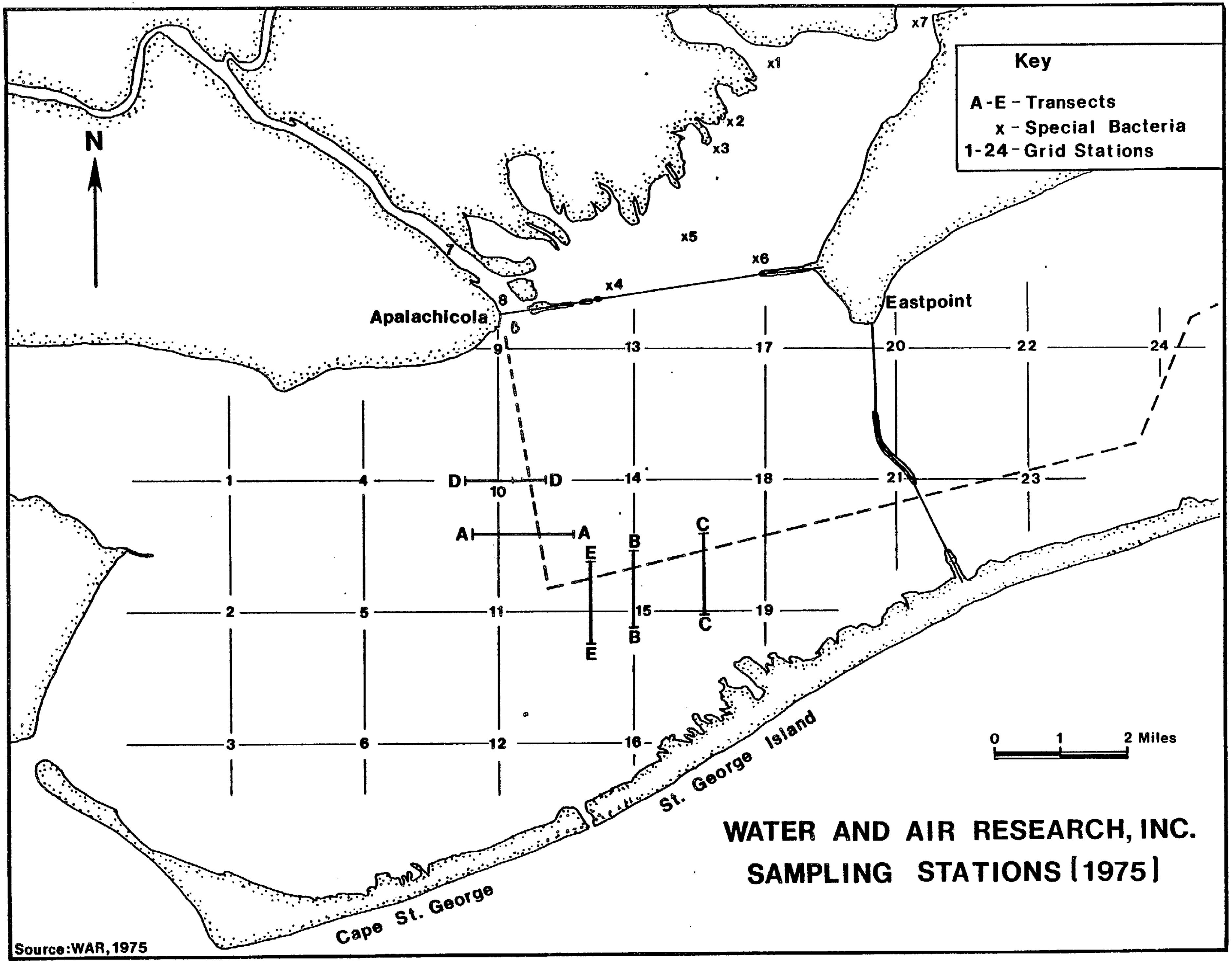
(5) provide funds for the DER to monitor bacteriological and heavy metal impacts associated with maintenance dredging.

The present study was initiated by the DER in 1982, with the objective of developing a long-term dredge disposal plan for joint implementation by DER and the COE. It represents an attempt to collect and review all available information on known or expected impacts of dredging in Apalachicola Bay. A similar effort has been completed for the Apalachicola River. Associated with the development of this plan, local fishermen were interviewed for their opinions concerning dredging in the bay. Finally, there are several issues which are still under study that will be discussed later in this section. The following is a summarization of previous research projects related to dredging impacts in Apalachicola Bay.

1. Water and Air Research (1975)

Water and Air Research, Inc. (WAR) assessed the environmental effects of maintenance dredging in Apalachicola Bay in 1974 (WAR, 1975). Hydrologic conditions, turbidity, suspended solids, sediment composition, heavy metals, coliform bacteria, plankton, and benthic invertebrates were analyzed. Sampling occurred before (February 15-18), during (March 15-22), and after (July 28-30) maintenance dredging of the Gulf Intracoastal Waterway in 1974. Sampling stations were established throughout the bay on a

Figure 25



Key
A-E - Transects
x - Special Bacteria
1-24 - Grid Stations
N
Apalachicola
Eastpoint
x1
x2
x3
x4
x5
x6
x7
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
A
B
C
D
E
0
1
2 Miles
St. George Island
Cape St. George
WATER AND AIR RESEARCH, INC.
SAMPLING STATIONS (1975)
Source: WAR, 1975

significant changes. Therefore, any effects of dredging which occurred during the WAR (1975) data collection period would likely be obscured by normal seasonal variations.

In addition, the limited sampling period of the WAR study, especially during dredging, might have missed significant data. For instance, dispersion studies showed that during dredging, turbidity plumes were detectable as far as 3500 feet from the point of discharge. However, since the area affected by the discharge plume varies with hydrological conditions, these values represent only a small range of possible situations. Futhermore, only one station which was impacted by disposal activities was sampled both before and after this disturbance. All the other stations involved were either not impacted by disposal activities or were not sampled during both periods. This station exhibited the smallest increase in both density and diversity of any station sampled during the study. A significant increase in these parameters occurred at all other stations due to natural seasonal variations from winter to summmer. This implies that this area was adversely affected by disposal activities and had not recovered fully within the 5 month period involved.

Problems involving sampling and analysis methods further reduce the credibility of the results. Figures V-9, V-10, and VI-3 through 6 in the WAR report show complex isopleths describing salinity, turbidity, and suspended solids at surface, middle, and bottom depths. However, according to the text, samples were taken at two-mile intervals. These complex isopleths cannot be reliably drawn from such widely-spaced data points. The dispersion data are graphically presented in Figures VI-8 through 15 of the WAR report. Again, it is not clear how the concentric isopleths could be drawn from the limited amount of data collected. Using visual observations to describe turbidity plumes can be misleading. For example, during a dredge plume study in Apalachicola Bay in March-April, 1984, visual observations of apparent turbidity levels did not correlate well with transmissometer readings (Burney, personal communication). Schubel, et al. (1978) also found areal differences between near-bottom and surface turbidity plumes.

Further problems concerning sampling and analysis procedures were found in the macroinvertebrate study. An increase in numbers and diversity was noted from pre-to post-dredging invertebrate samples due to seasonality (as expected in any warm-temperate estuarine system). However, several methods were altered in the post-dredging sampling and analysis including:

1) A newer sampler with a stronger closing spring was used in the post-dredging sampling;

2) Rose Bengal stain, which makes infauna more visible to sorters, was added to post-dredging samples; and

3) There was a possible increased efficiency of sorters, and greater care in sampling and processing after dredging.

The alteration of methods, especially when examining before and after effects, is poor scientific protocol and reduces the credibility of the analysis.

In summation, the report's conclusion, that no significant environmental impacts are caused by dredging and disposal in

Figure 26

TAYLOR [1978] STUDY SITES

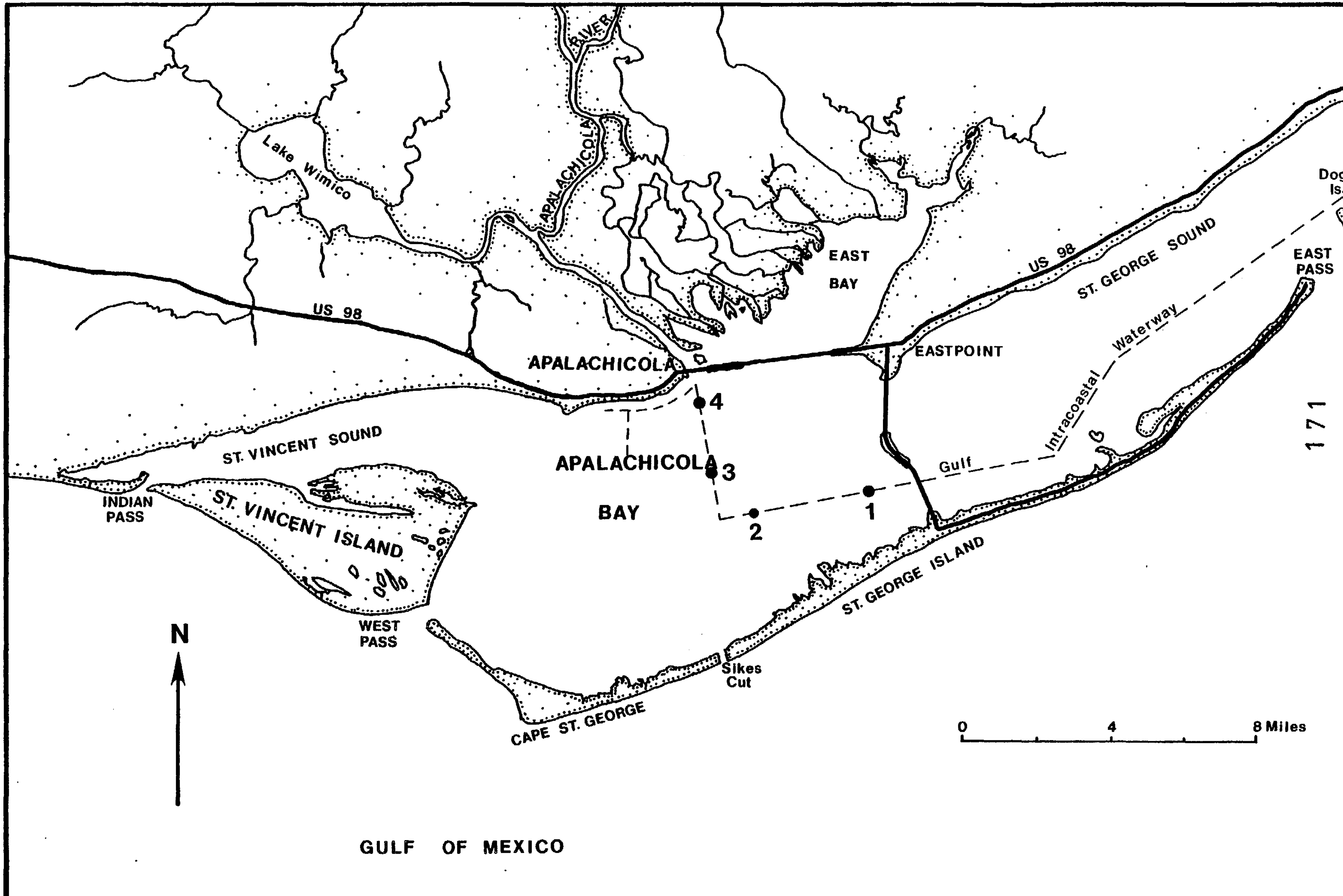
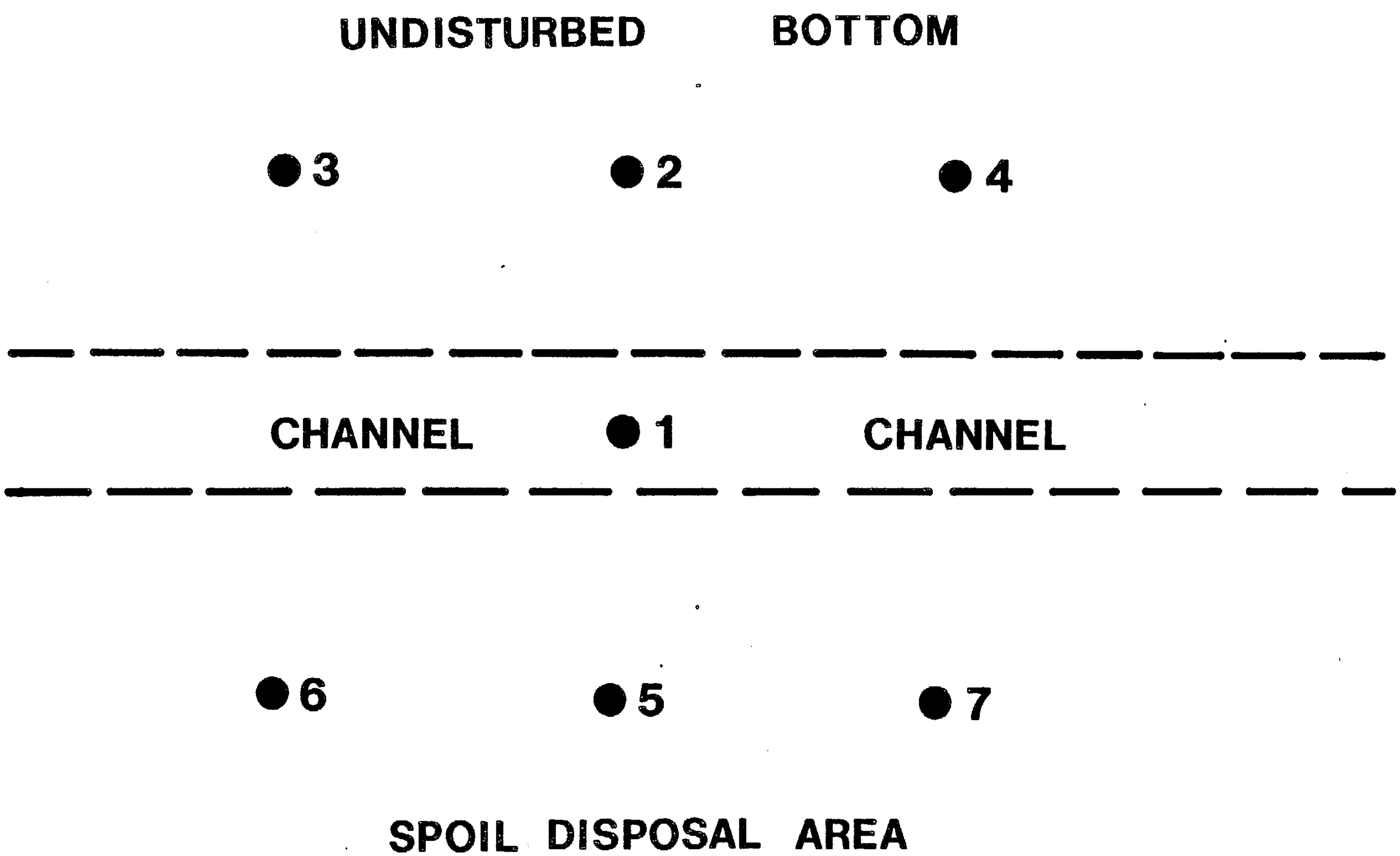


Figure 27

Sampling scheme used in Taylor [1978]



According to Taylor (1978), "Channel and maintenance dredging operations have disrupted this system in the past and will do so in the future. In most instances alterations caused by previous dredging have been localized and largely temporary, a conclusion supported in other waterway studies and corroborated here.

"Even though permanent adverse effects on sediments and benthos were demonstrated from dredging at channel stations (high silt content and low species diversity and abundance), such ecological damage is unavoidable if the GIWW is to be maintained. At disposal areas and undisturbed areas, data for sediments and benthos were essentially indistinguishable, even at sites that have undergone recent maintenance dredging. Therefore, sedimentological, hydrological, and biological disturbances known to occur during dredging operations are very likely of short-term duration at disposal sites and in adjacent areas free of seagrasses and oyster reefs.

"Considering the general environmental characteristics of the GIWW (chemical, physical, and biological), it would appear that the major concern that must be addressed in future dredging projects is the potentially adverse effect of suspended sediments and mud flows on aquatic vegetation and oysters."

Taylor (1978) recommended use of upland disposal methods or creation of diked disposal islands in open water, and suggested that these alternatives would offer the following advantages over open water disposal: 1) the silts and clays resuspended in dredging operations could be confined and stabilized more satisfactorily; 2) sand and shell material removed from channels could be stockpiled and used by the public; 3) permanent removal of sediments from channels may reduce the need for frequent maintenance dredging; and 4) environmental controversy would be eliminated, allowing agencies to develop long-term management programs for coastal waters in the northeastern Gulf of Mexico.

After closely reviewing Taylor (1978), several problems were found with this study effort. The study assumed that sediment across the channel from disposal sites is undisturbed and not affected by the dredging and disposal process, and therefore represents an adequate control site for evaluation of effects of dredging. However, personal observations in Apalachicola Bay, including monitoring of dredge events and discussions with local oystermen, do not support this assumption. For instance, oyster lumps found on the "undisturbed" side of the north-south leg of the GIWW were found to be covered with several inches of fine black sediment after the March-April dredging in 1984. Furthermore, COE monitoring data for the GIWW collected in 1984 noted that turbidity plumes sometimes extended back across the channel, under the dredge, to the "undisturbed" side. Therefore, the conclusion that data for sediments and benthos were essentially indistinguishable at disposal areas and undisturbed areas is questionable since the undisturbed sites may have been impacted by dredging activities.

Data from a single set of samples per site taken in the winter is not sufficient information to adequately assess the biological importance of any area. Four replicate samples were taken for benthic biota analysis, but no rationale was given for this number. During previous benthic work done in the bay, ten cores per station were always taken to assure 90% species accumulation (Livingston, et al., 1976; Livingston, personal communication.). Problems in labelling the sampling grid diagrams and in the use of a pro-rating procedure for numerical analyses and statistics further limit the usefullness of this study.

Analyses of sedimentological and biological data are based mostly upon averages taken from all 28 sites along the GIWW. This approach is excessively general, and does not reflect real differences in habitat, sediments, biota, and localized dredge-related problems. A better approach might have been to analyze groups of sites with similar habitat characteristics.

The recommendations of disposal islands for GIWW disposal material are overly general, and not well supported. A site-by-site or habitat-by-habitat series of recommendations would have been far more pertinent. In Apalachicola Bay, open-water diked disposal islands could be easily eroded by storms and wave action. As an example, the shell island next to Patton Bridge was completely eroded recently. In addition, the effects of diked islands on circulation patterns were not considered. Permanent removal of dredged material from the system probably would not reduce the need for maintenance dredging in Apalachicola Bay because of the constant influx of sediment from the river as well as the shifting of sediments in the bay by storms. Creation of disposal islands could also create obstructions to navigation and fishing. In addition the removal of bay bottom from potential oyster or shrimp production would not be supported by area fishermen and, therefore, would not eliminate environmental controversy.

In summation, Taylor (1978) provides a lot of sediment data from 28 sites over a 340 mile stretch of the GIWW. However, the report does not adequately address the question of negative or long-term effects of maintenance dredging at disposal and undisturbed sites. The general approach taken in this study, and its conclusions, show little sensitivity to individual habitat differences and the actual effects of dredging at GIWW sites in Apalachicola Bay.

3. Livingston (1984a)

In conjunction with the preparation of a dredged material disposal plan for Apalachicola Bay, Dr. R. J. Livingston of Florida State University was contracted by DER to determine if the long-term data base developed under his guidance indicated that there were any impacts from maintenance dredging in the Apalachicola Bay system on key water quality factors or biological parameters. Physical, chemical, and biological data were collected (usually monthly) during eleven years of sampling from March, 1972, to July, 1983. A series of 55 stations were established in the lower Apalachicola River and tributaries, East Bay, Apalachicola Bay, St. Vincent Sound, and western St. George Sound. Original station placement began in 1972, and permanent, or fixed stations from this area were used for this report, particularly Stations 1, 2, 3, 5, 1a, 1b, and 1c (Figure 7). Other stations were more recently established for various other research purposes. Four of the permanent stations on in this study were located near dredged channels: Station 1, near the Two Mile breakwater; Station 2, on the north-south leg of the GIWW; Station 1c on the east-west leg of the GIWW; and Station 1b near Sikes Cut.

The long-term data were used to evaluate dredging effects on a local and bay-wide basis. Short-term effects connected to specific dredge events and storms were also examined. The data were extensively processed statistically in an effort to separate out effects of dredging from natural variability.

The study concluded that salinity at Sikes Cut was spatially and temporally related to dredging activities in the area. Shifts were observed in the fish and invertebrate communities (numbers of individuals, species richness, and diversity) due to salinity changes resulting from the cessation of dredging in Sikes Cut in 1978. Livingston (1984a) found no short-term effects on water quality parameters and biological indices from dredging operations in the Gulf Intracoastal Waterway and the Two Mile extension channel during winter months. And, no significant long-term changes in habitat features were evident at stations that could have been affected by the opening of the Two Mile extension channel in 1976.

The dredged sections of the Gulf Intracoastal Waterway Channel, the Two Mile Channel, and the Eastpoint Channel were found to be depositories of silt-laden sediment contaminated with heavy metals and organic matter. The deposition of these contaminants was believed to be related to the proximity of urban runoff, circulation conditions, and other seasonally changing variables. Nearshore channels were characterized by biological degradation, while open-water channels were generally unaffected.

The overall analysis of dredging activities in the bay suggested that dredging can affect the salinity regime and the biological productivity of the system. Livingston (1984a) recommends that dredging of the bay be restricted to winter and early spring months to minimize the possibility of adverse effects on commercially important species which utilize the area as a nursery ground during spring, summer, and fall months.

One problem associated with the conclusions of Livingston (1984a) is that the sampling stations used to evaluate impacts were designed to provide an ecological characterization of the estuary, not to evaluate the effects of dredging. Therefore, even with the use of statistical techniques designed to separate natural and seasonal variability from dredging events, the data in Livingston (1984a) is open to differing interpretations and do not conclusively indicate that differences in salinity regime and biological productivity resulted from dredging activities. This limitation was recognized at the onset of this evaluation. Nevertheless, it was felt that an assessment of Dr. Livingston's extensive data base on the estuary could provide valuble insights to understanding the impacts of dredging on the estuary.

Another problems associated with Livingston (1984a) were that bottom salinities at Sikes Cut were reported to be related to dredging events, and that after the cessation of dredging, bottom salinities were generally lower. However, this phenomenon seems to have begun in mid-1977, while dredging of the cut did not cease until mid-1978. Additionally, the data show that Sikes Cut and West Pass generally follow similar trends throughout the study, even though one has been dredged, and the other has not. (Refer to Figures 19, 20, 44 through 54 in Livingston (1984a) for data mentioned above.) Livingston (1984a) noted that no short-term effects of dredging were found during winter months. However, the data also indicate that there were no short-term effects of dredging during spring or summer months (Refer to Figures 22 to 40 in Livingston (1984a).

4. Schubel, et al. (1978)

Apalachicola Bay was one of three bays studied by Schubel, et al. (1978). Sampling in Apalachicola Bay occurred in April, 1977 before and during maintenance dredging in the Gulf Intracoastal Waterway. The primary thrust of the research was to determine the effects of different discharge configurations on the size and intensity of the disposal plume. Four different discharge configurations were tested: above water with a deflector plate, below water with a deflector plate, above water without a deflector plate, and below water without a deflector plate. Water samples were taken before and during dredging for nutrient and metal analysis, and sediment cores were taken from the channel prior to dredging for nutrient, metals, and grain size analysis. A secondary study to determine increased biochemical oxygen demand caused by dredging was also undertaken.

Using transmissometer data, concentrations of total suspended solids were calculated using calibration curves for surface and bottom waters. Due to the abundance of suspended organic matter, the use of these calibration curves results in an over-estimate of the actual concentration of suspended solids. Background values collected prior to dredging had a range of concentration of suspended solids of 25-150 mg/l. Most concentrations were within the 25-50 mg/l range. Concentrations of suspended solids measured in the discharge plume during dredging were generally below 200 mg/l. However, concentrations in excess of 500 mg/l were measured in near surface waters and in excess of 2000 mg/l in near bottom waters on numerous occasions. The areal extent of the discharge plumes were estimated using 50 mg/l isopleths. The largest plume covered an area of about 100 acres and extended 1.3 miles from the discharge pipe. The near-bottom plume almost always covered an area substantially larger than the near-surface plume.

Schubel, et al. (1978) also measured current speed and direction during dredging but could not correlate the data with plume orientation. Wind speed and direction data also could not be correlated with plume orientation. Using three separate methods to measure the partitioning of the sediment discharged, they estimated that only 1% of total mass of sediment discharged was incorporated into the plume. The remaining 99% settled rapidly to the bottom near the discharge point. Much of this unconsolidated material can be incorporated into a mud flow or fluid mud layer. This layer is caused by flocculation and the settling out of the unconsolidated material and results in a mobile sheet of mud. Areas subject to fluid mud formation are those with high concentrations of silt and clay in the sediments being dredged. Therefore, based on available sediment data, it appears the GIWW and Eastpoint Channels are the dredged areas most prone to fluid mud formation.

Data from Schubel, et al. (1978) indicate that a deflector plate in front of the discharge pipe seemed to reduce the areal extent of the near-surface plume. The data also suggest that discharge above water without a deflector plate presents a worst-case condition with regard to areal extent of the near-surface plume. Data concerning effects of differing discharge techniques on the near-bottom plume were more variable and could not be readily discerned.

A secondary study was undertaken to determine short-term changes due to dredging in concentrations of nutrients and metals in the sediments and water column. Sediments in the channel prior to dredging were predominantly clay (68%) and silt (31%) with a small amount of sand (1%). Water content was approximately 70% by wet mass. Carbon was about 10%. Analysis of water column dissolved metal concentrations of iron, manganese, copper, and chromium before and during dredging showed no significant increase in average concentrations. No well defined plumes of nutrients were detected during dredging, although ammonium (NH_4^+) and reactive silica ($Si(OH)_4$) concentrations increased, suggesting these two nutrients were released, probably from interstitial waters. Orthophosphate (PO_4^{-3}) concentrations showed no observable change. Analysis of sediment cores showed that metal and nutrient concentrations were comparable to other studies' findings.

Schubel, et al. (1978) also measured dissolved oxygen (DO) concentrations and observed a small oxygen sag due to maintenance dredging and disposal. They calculated an oxygen demand of about 0.4 mg O_2/g of dry sediment in Apalachicola Bay. They indicated that the oxygen sag was smaller than would be predicted from either organic carbon content or the total reducing capacity of the original sediment. From this and other data, Schubel, et al. (1978) concluded that observed oxygen sags are largely the result of oxidation of dissolved constituents in interstitial waters and perhaps to some extent the oxidation of the surfaces of sulfide minerals.

This study appears to be a well defined report that makes positive contributions towards the understanding of how dredging effects the Apalachicola ecosystem. However, a problem associated with the study was related to the location of the current meters and wind collection equipment which made correlation with the plume orientation data impossible. The sampling tracks during the plume studies also appear to be biased in specific directions. Almost all sampling was done south or east of the discharge pipe. The plume is well defined in these areas because of the amount of data; however, due to the lack of data north and west of the discharge, the actual extent of the plume is questionable. If the tracks were determined by visual observation of the surface plume it is possible that the extent of the near bottom plume is underestimated. The authors note that the water column was stratified during much of the study.

5. **Kruczynski, et al. (1978)**

The Habitat Development Project of the Dredged Material Research Program (WES, Vicksburg) conducted a field study of marsh habitat development in Apalachicola Bay (Kruczynski, et al., 1978). The project was designed to test the feasibility of propagating marsh plants on coarse- and fine-grained dredged material in an intertidal environment and to determine optimum spacing between plants. The results were expected to be applicable to efforts at stabilization of dredged material in other estuarine environments.

The project site was Drake Wilson Island, one of two disposal islands near Two Mile. The two islands were diked, and coarse dredged material was pumped in during the Two Mile Channel dredging in March, 1976. On Drake Wilson Island a weir was built into the dike, permitting tidal influx similar to local marshes. Fine-grain dredged material was then pumped on top of the coarse material and dispersed through the intertidal area.

The two marsh plants chosen for this study were smooth cordgrass, to be planted on fine-grained material, and saltmeadow cordgrass, to be planted in coarse-grained sediment. Transplants were obtained from intertidal marsh areas on St. Vincent Island, and were planted at elevations similar to those of their original location. Sprigs of both species were planted in experimental plots of different sizes, spaced 0.3, 0.9, 1.8, and 2.7 meters apart in July, 1976. Variables were then monitored 5, 9, and 14 months after planting. At these times a floristic survey of the island was made to document natural invasion by plants.

Both species exhibited substantial growth fourteen months after planting. Smooth cordgrass growth improved as spacing decreased. At the 1.8 and 2.7 meter intervals tidal energy from the nearby weir was apparently too great for the sprigs placed far apart in unconsolidated materials. Plant cover resulting from the 0.3, 0.6, 0.9 meter spacing intervals was visibly comparable with nearby native smooth cordgrass marshes. In the saltmeadow cordgrass plots, growth improved as planting interval increased, with best growth at intervals of 1.8 and 2.7 meters.

The authors recommend that plantings be used to stabilize dredged material sites, since natural invasion and development of sufficient ground cover is happenstance. They also recommend prior to any large-scale marsh development, choosing appropriate species (which provide ground cover quickly, stabilize substrate, and become predominant primary producers in the estuarine food chain), conducting a floristic survey of environmentally similar areas, and conducting a small-scale feasibility study.

This report shows that successful stabilization of dredged material and creation of marsh habitat is feasible in Apalachicola Bay. Some additional information would have been valuable to the reader. The ecological requirements of the two species chosen for planting were not described. This information alone would probably have clarified why smooth cordgrass was planted in fine-grained sediment with higher organic content, and saltmeadow cordgrass was planted in coarse-grained material with low organic levels. No explanation was given for the substantial difference in experimental treatments of the two species. In the smooth cordgrass study numerous plots of different sizes were planted, each with a replicate, and there was a designated control plot with a replicate. The area planted totalled 2650 square meters and was oriented east to west. In the saltmeadow cordgrass study four large plots were planted, there were no replicates, and spaces between the plots were considered control sites. The total area planted was 331 square meters and plots were oriented north to south.

An additional section on the economic feasibility of this project and application of the results to a full-scale marsh development study for the Apalachicola Bay area would have been useful. The results and recommendations of this study may prove to be of practical value when alternatives to open-water disposal in Apalachicola Bay are considered.

6. COE Environmental Assessments and Impact Statements

In conjunction with the maintenance dredging of navigation channels in Apalachicola Bay, the COE has reviewed environmental impacts associated with their activities. The impacts from maintenance dredging on the GIWW are discussed in COE (1976) and COE (1981), and the impacts associated with the bay projects are discussed in COE (1974) and COE (1982). Most of the conclusions reached in these reports are based on the findings of WAR (1975) and Taylor (1978), or research done in the COE's Dredged Material Research Program. WAR (1975) and Taylor (1978) have been discussed in depth earlier in this document.

In general these reports acknowledge that maintenance dredging will impact water quality, but the impacts are expected to be minor, short-term, and of limited areal extent (COE, 1981). It is noted that in naturally turbid estuaries such as Apalachicola Bay, the potential for detrimental impacts from increased turbidities caused by dredging are less than in clear water systems. Studies from the COE's Dredged Material Research Program contended that in areas such as Apalachicola Bay, turbidity is primarily a matter of aesthetic impact, rather than biological impact (Saucier, et al., 1978), because the biota is adapted to living in conditions where turbidity levels fluctuate. COE (1981) further contends that the effects of turbidity from maintenance dredging on the overall bay are small and of short duration. The natural effects of wind, weather, and floods on suspended sediments and turbidities are believed by the COE to be greater than those of dredging, and much more frequent. WAR (1975) found that turbidity plumes from maintenance dredging were not detectable within a few hours after dredging ceased. Differences in the composition of bottom material between disposal areas and adjacent undisturbed areas exist on the GIWW at the eastern part of Disposal Site 1 and at Disposal Site 2 in Apalachicola Bay (COE, 1981). These differences are believed to be due to past disposal practices, original construction, and/or maintenance. Continued use of these sites is not expected by the COE to have long-term effects on the current conditions or the existing benthic community. At all other open water sites on the GIWW, channel sediment types are similar to disposal area sediments, and, therefore, bottom composition changes are not expected. COE (1982) does not expect any significant changes in the physical composition of bottom material for Sikes Cut or Two Mile Channel. At the Eastpoint Channel, however, the physical characteristics of the proposed disposal sites could temporarily change because the disposal material contains about 30% more fine-grained sediment than disposal site material.

COE (1982) notes that all disposal material placed in open-water, on beaches, or on islands would experience some migration. Hydrographic surveys of open-water sites indicate that bathymetric changes due to the buildup of dredged material have occurred at the eastern end of Disposal Site 1, northern end of Disposal Site 2, and at Disposal Site 2.2 of the GIWW. Continued buildup is only expected at Site 2.1 because this site is in a naturally shallow area (COE, 1981). No significant impacts on circulation are expected from this buildup.

COE (1981) and COE (1982) note that no evidence exists to support the conclusion that sediment buildup from previous disposal operations has affected salinity distribution in the bay. COE (1982) further contends that the St. George Island Cut has had only a localized impact upon the bay's salinity gradients.

According to COE (1982), chemical analysis of sediments did not indicate concentrations of chemical contaminants in toxic amounts, and any release of chemical constituents that might occur were not expected to be a threat to the bay ecosystem. No significant cumulative effects on dissolved oxygen or toxic and metal content in the water were foreseen from the bay projects.

Elutriate tests indicated possible violations of Florida Water Quality Standards for copper and iron at the Eastpoint and Two Mile Channels at the point of discharge. However, outside the 150 meter mixing zone, turbidity was the only parameter expected to have potential for violation (COE, 1981; COE, 1982).

In regard to impacts upon the aquatic ecosystem, the COE (1981) and COE (1982) maintain that since dredging activities have been ongoing for many years and no significant cumulative impacts have been identified, none exist. The COE (1974, 1981, 1982) claim impacts are insignificant because: 1) the relative amount of area disturbed by dredging and disposal practice is small when compared to the entire bay; and 2) for the most part the disposal sites and channels are not located in ecologically critical areas. The impacts on benthic communities at open water sites are believed to be minor because dredged material and disposal site materials are similar in most cases (COE, 1981; 1982). Impacts on nekton are expected to be minimal because of the ability of this group to swim away (COE, 1981; 1982). Impacts upon planktonic communities are expected to be temporary and localized, and not result in measureable impacts on local or regional populations (COE, 1982).

According to COE (1982) disposal practices have resulted in benefits to the aquatic ecosystem by the creation of marsh habitat at Two Mile and by increasing shallow habitat for submerged vegetation through elevating the bay bottom, although a detailed description of these benefits was not provided. With the exception of the marsh planted at Two Mile Breakwater, CSA (1985a) and Livingston (1980) have identified no new marshes or sea grass beds associated with disposal sites. There have been reports of oyster bars developing on the disposal sites of the GIWW during the period the channel was not maintenance dredged (i.e., 1979-1983). However, once maintenance dredging was resumed most of these developing bars were apparently buried either directly or by migration of material after disposal.

The extent of impact depends on the proximity of ecologically sensitive habitats. In the GIWW, disposal areas on the east-west leg are within 1500 feet of productive oyster bars, and much of the channel and disposal sites are located in approved shellfish harvesting areas. However, COE (1981) notes that dredging and open-water disposal have occurred at these sites for years without any known damage to these oyster bars. Dense sediment flows (i.e., fluid mud) are considered to have the most potential for impact. COE (1981) states that mud flows have not been found to significantly affect oyster bars because fluid mud travels along the bottom and oyster reefs are elevated. Since disposal material at Eastpoint, Two Mile, and St. George Island Channels are placed no closer than 1300, 3600, and 20,000 feet from the nearest oyster beds, COE (1978) expects no critical damage to sensitive habitats. COE (1974) further notes that no oyster mortalities or reduction in oyster production from dredging and disposal operations have ever been reported.

These COE reports also note that the timing of dredging can minimize potential impacts on the bay ecosystem. By limiting dredging within the bay to winter months, potential damage to the oyster spawning season would be avoided, as would the damage to critical life cycle stages of many other bay species (COE, 1974; COE, 1982). COE (1982) further notes that no disposal should be placed on the St. George Island beach disposal area from April through October to protect the nesting sites of loggerhead turtles.

COE (1981) and COE (1982) noted that although benthic communities would be covered by disposal practices, recovery would begin within a few months and be complete within six months to two years depending upon the location. Repopulation is expected to be most rapid in fine-grained sediment. The recovery time for areas covered by mud flows is expected to be less than that for disposal areas (COE, 1976), however, continued and frequent use of disposal areas represents a long-term impact because the site never has time to recover.

There are two major problem areas associated with the COE environmental assessments and environmental impact statements. The first is that WAR (1975) and Taylor (1978) are used to support the conclusions drawn in these documents. The problems associated with WAR (1975) and Taylor (1978) are discussed earlier in this section. The second is the report's tendency to treat unsubstantiated hypotheses and assumptions as documented facts. For instance, in COE (1982) it is contended that St. George Island Channel has had no impacts upon the bay's salinity gradient, yet, the question as to whether the St. George Island Channel has impacted salinity gradients in the bay has still not been resolved. In fact, monitoring of salinity was a requirement of the 1984 permit to dredge the cut, and an evaluation of this issue is currently underway. COE (1981) and COE (1982) additionally contend that no evidence exists to support the conclusion (actually a hypothesis) that sediment buildup from previous disposal operations has affected salinity distribution in the bay, and therefore, assume no impact has occurred. However, no information to support their conclusion is provided.

Because of their tendency to be written as advocacy documents instead of evaluative assessments, the existing COE environmental assessments and impact statements for navigation projects in Apalachicola Bay do not provide an objective and comprehensive evaluation of the impacts of dredging and disposal activities on the Apalachicola estuary.

7. Monitoring Data and Studies Required by Permits

As discussed earlier a number of monitoring and study efforts have been required by DER permits to assist the Department in evaluating the impacts of dredging and disposal in the estuary. A review of the data provided to the DER follows.

a. Sikes Cut

The permit for dredging Sikes Cut which was issued in December, 1983 required the COE to monitor salinity at the channel before and after maintenance dredging to provide a better understanding of salinity changes caused by the cut. Data collected in this effort included: 1) water temperature, 2) salinity, 3) depth of water body, 4) depth of sample, 5) antecedent weather conditions, 6) tidal stage and direction of flow, and 7) wind direction and velocity. These data were submitted to the DER in April, 1984. Analysis of these data in COE (1985) showed that the data agreed with the findings of Mehta and Zeh (1980), that the influence of the cut on the bay's salinity regime was localized, and subsequently that the impact upon the oyster reefs was minimal. A more detailed discussion of these data and the impacts of Sikes cut on the estuary's salinity regime is provided later in this section.

b. Eastpoint

In conjunction with the construction of the Eastpoint Breakwater, the permit required the COE to monitor water quality and to measure current velocity and direction before and after construction. This monitoring was required because of concerns of impacts on the nearby Cat Point oyster bar. Water quality monitoring was to consist of DO, temperature, pH, and salinity readings taken at the top, middle, and bottom of the water column at four hour intervals over a 24 hour period. In addition, once each 24 hour sampling period, BOD and fecal coliforms were to be sampled at mid-depth. Three stations were established to measure current velocity and direction. The stations were in the Eastpoint Channel at the middle, eastern, and western extremities of the breakwater. Measurements consisted of top, middle, and bottom readings at 4-hour intervals over a 24-hour period, once before construction began and then once per quarter for four quarters after construction was completed. Tidal and wind velocity data were recorded during each monitoring period. In reviewing these data no conclusions could be made in regard to the

Raney, et al. (1983). The study acknowledged that water quality conditions landward of the breakwater would probably deteriorate slightly; but since water quality there was already poor, the effect from the breakwater is expected to be minimal. Livingston (1983b) also concluded thjat dredging and breakwater construction would have adverse effects on the benthic habitat in localized areas, but these effects should be relatively transitory. The loss of habitat due to placement of rock and dredged material would also be mitigated to a certain degree by the new habitat provided by the breakwater.

High levels of oils and greases, nutrients, and metals such as copper, iron, lead, and zinc were found in sediments in the Eastpoint Channel area. These pollutants are associated with the fine silt and clay particles in the sediment and their presence is probably due to urban runoff, boat traffic, and direct discharge of washdown water from seafood processing houses. Again Livingston (1983b) concluded that there should be minimal effects on Apalachicola Bay due to open water disposal of these dredged sediments. He also concluded that the environmental impact should be limited to the immediate area around Eastpoint and should not have long-term adverse effects on the water quality or benthic community.

In 1983 the COE and DER signed an agreement in regard to monitoring conditions for dredging of the Eastpoint Channel. It was agreed that prior to disposal operations, fourteen sampling sites would be designated south of the breakwater. Parameters to measured include DO, temperature, pH, salinity, turbidity and fecal coliform. The water column is to be evaluated for nutrients (NO_2, NO_3, NH_4^+, TKN and total P), a variety of metals (Al, Cu, Fe, Hg, Pb, and Zn) and oils and greases. Bottom sediments are to be sampled for organic fraction, oils and greases, metals (Al, Cu, Fe, Hg, Pb and Zn) and particle size. Benthic macroinvertebarates are to be collected at eight sites and oyster tissue samples are to be taken from several sites along the eastern and western oyster bars and composited for fecal coliform and heavy metal analyses. And, post-disposal bathymetry profiles are to be taken for three weeks following the completion of disposal operations to define bottom changes.

c. Gulf Intracoastal Waterway

In conjunction with the 1984 permit for maintenance dredging the GIWW, the DER required the COE to monitor bathymetry and turbidity at open-water disposal areas, and to fund bacteriological and heavy metals monitoring. Furthermore, the permit required the COE to complete development of a mathematical model to simulate hydrodynamic and salinty effects in the estuary and to conduct a study on fluid mud flows. Data submitted by the COE taken during the 1984 dredging of the GIWW show turbidity values generally ranged from about 25 to 200 NTU's 500 feet from the discharge pipe. Several samples taken near the bottom, at a distance of 500 feet, showed turbidity levels in excess of 1000 NTU's. Exact ranges were difficult to determine since the turbidity meter would not read above 1000 NTU's. Turbidity values of over 80 NTU's were also recorded as far as 3500 feet from the discharge pipe in approximately 30% of the samples. Based on results of turbidity plume sampling during the 1984 GIWW dredging, Ryan, et al. (in prep) concluded that sediment remobilization during dredging is similar to that from natural episodes. However, they also found that secondary resuspension from disposal areas appears to provide a major contribution to turbidity and total suspended solid levels in their vicinity.

In several instances the turbidity plume extended back across the channel, under the dredge, to the "undisturbed side of the channel." On several calm days turbidity levels were higher at mid-depth than at the bottom. This condition was probably caused by a stratified water column in which particles (and organisms) tend to collect at the discontinuity layer, although this hypothesis cannot be verified since salinity values were not reported.

To satisfy permit conditions the COE contracted the DER to monitor metals and nutrients in the sediment and water column adjacent to the GIWW. The DER monitored eleven stations along the GIWW in spring 1984 for a variety of parameters. As discussed earlier, these results indicated high absolute concentrations of arsenic, cadmium, chromium, copper, zinc, and ammonia-nitrate associated with the sediments. However, when these concentrations are normalized using metal-to-aluminum ratios, only cadmium, chromium and zinc appear to not be from natural sources. This study (Ryan, et al, in prep) further found that secondary sediment resuspension from previously used disposal areas contributed significantly to turbidity and TSS levels in the vicinity of the disposal area.

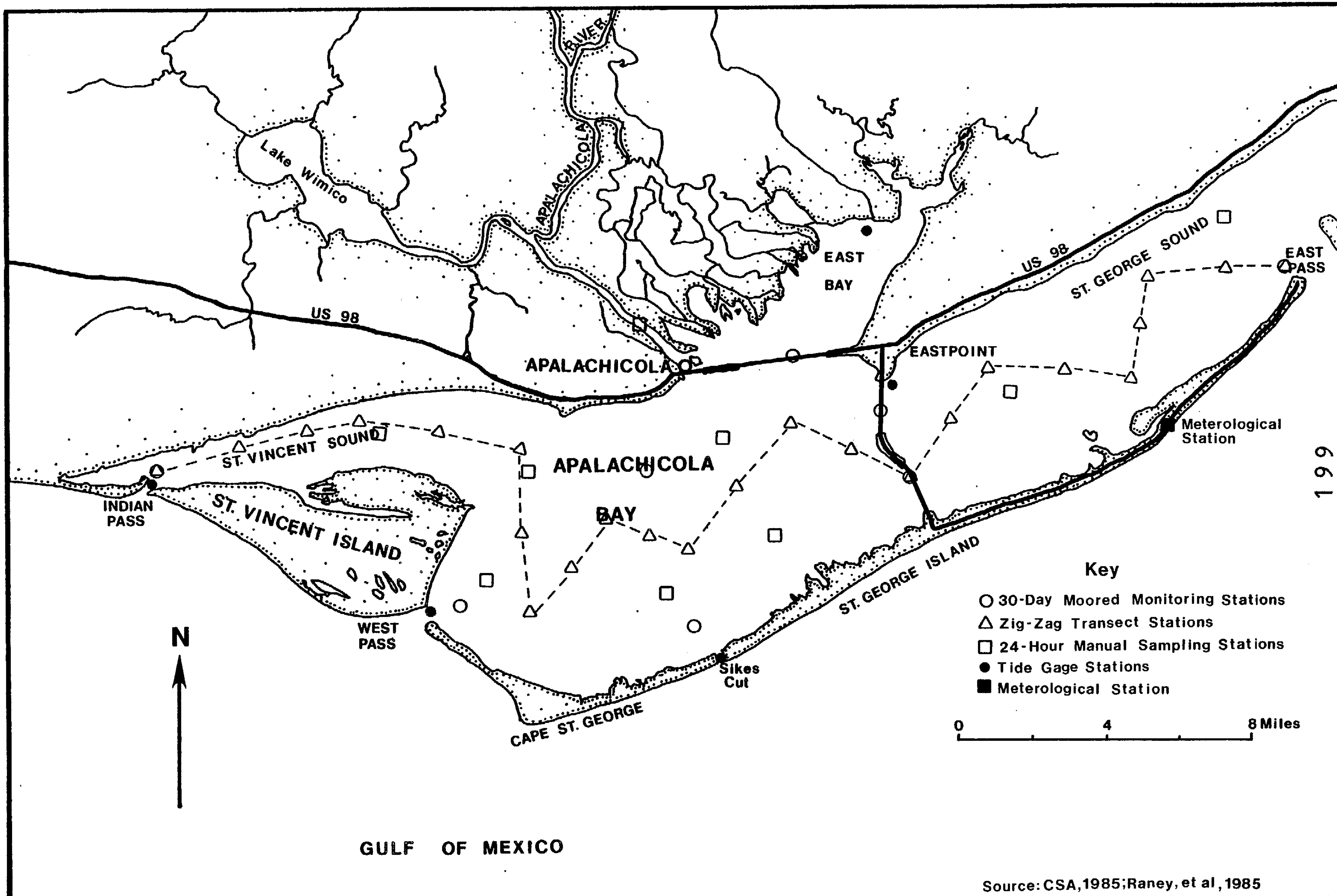
Ryan, et al (in prep) also found that there is a relationship between the amount of nutrients released into the water column and the volume of sediment put into suspension. However, this release is poorly predicted by elutriate testing. Nutrient concentrations (PO_4 and NO_3) in the plume were found to be closely related to TSS and TOC concentrations. A good correlation was also found between NH_3 and TKN, with the majority of the TKN being in the form of ionized ammonia.

(1) **Hydrodynamic and Water Quality Model of the Bay:** A numerical model to simulate the hydrodynamic and salinity regimes in Apalachicola Bay and the adjacent waters of St. George Sound, East Bay, and St. Vincent Sound has been developed. This model was adapted to the estuary by Dr. Donald Raney of the University of Alabama, and became available in December, 1985. The model selected for use was a previously existing, two-dimensional, finite difference model. This model was adapted to the Apalachicola estuary using a portion of a large data set collected during two thirty-day monitoring periods: one in September, 1983, and one in March, 1984. The data set for this study effort consisted of:

1) water current speed and direction, conductivity, and temperature measurements continuously recorded at nine moored stations positioned throughout the Apalachicola Bay system;
2) wind speed and direction recorded from one station on St. George Island;
3) six water quality zig-zag transects (one at the beginning, middle, and end of each thirty-day sampling

Figure 28

STATION LOCATIONS FOR HYDRODYNAMIC MODEL DATA COLLECTION



forced to satisfy boundary conditions at the bottom and surface of the water column (Raney and Youngblood, 1983). The model is only capable of reliably projecting conditions in the estuary for a period of several days into the future. In conjunction with the ongoing study of the impacts of Sikes Cut on the estuary, an evaluation of the utility of this model for determining impacts in the estuary was done (Weisberg, 1986). This evaluation concluded that this numerical model is limited as an environmental impact assessment tool because of its simplifications and boundary condition data. Specific questions were raised regarding the calibration and verification of the model, and the simplifications of vertical averaging and dynamic decoupling of momentum and salinity conservation equations. A concern was also raised as to whether the tide gages used to provide sea level boundary condition data had been accurately levelled. As a result of these comments some modifications are being made to the model.

(2) **Fluid Mud Flow Study:** The COE contracted with the U.S Geological Survey (USGS) to gather data to determine the extent that deposited dredged material migrated as a fluid mud layer along the bay bottom during the April 1984 dredging of the north-south leg of the GIWW . Calibrated fathometer readings and sediment cores for bulk density were taken along eight parallel ranges that lie perpendicular to the GIWW channel. Fathometer readings began 1000 feet east of the channel and were recorded every 50 feet westward for 5500 feet. At least five cores were taken along each range: one between the channel and disposal site, three on the disposal site, and one about 500 feet west of

the disposal site. Seven sets of samples were taken: one before dredging and six after dredging at irregular intervals for about 9-10 weeks after deposition. The raw data (USGS, 1984) has been provided to the COE and DER. In addition, the COE has made a review and analysis of the data (Imsand, 1986) and the USGS has made an unpublished, preliminary analysis (Rumenik, personal communication). Upon examination of the study proposal and these documents project staff has the following comments:

1) There is serious question as to the efficiency of a fathometer, even if it is highly calibrated, to measure a low density, relatively thin layer of material such as fluid mud. A better tool would have been a sediment-water interface probe as suggested in Nichols, et al. (1978). This alternative was advised by DER staff in the planning phase of the study. Therefore, the utility of the data in defining the limits of the problem is open to question;

2) The study plan called for depth readings and core samples to be taken to about 6000 feet west of the disposal areas (a total run of about 10,000 ft.). This range of samples was taken only on the pre-dredge run and final run for fathometer readings. Instead, depth recordings and core samples were taken only to about 2000 feet west and 500 feet past the disposal site, respectively. Although it is implied that this distance encompasses the extent of the mud flow, no justification is given for this assumption. The data seem to indicate that some of the material also drifted to the east off the disposal site and into the channel. The distance and

amount of material which drifted into the eastern quadrant was not addressed in Imsand (1986). These problems are important since the study's objective was to see how far dredged material moves off the disposal site;

3) Fathometer readings indicated a great deal of shifting over time within disposal boundaries, which may be due to either inaccuracy of readings or station locations, or a resuspension of the material. Even allowing for extensive variation due to sampling error, some broad generalizations are noted from the depth profiles. In the main part of the disposal area, deposition is up to one foot thick and covers a large area. The first profile, made about 4 days after dredging, is very different from the others taken 2-10 weeks after disposal. The initial profile indicates a depositional area that is much broader, in some ranges extending well past the disposal site, and more uniform in depth. Though peaks in disposal material depths are similar in the first and later runs, it is apparent from the narrower margins of the peaks and more numerous 'valleys' in later run profiles, that volumes of material either moved off of the site or became considerably more packed (not reflected in bulk density values). It appears to have moved away after a short residence time, indicating that either the fathometer is not registering the low density materials or that waves and currents are resuspending much of the material. Imsand (1986) acknowledges that disposal material moves up to 2200 feet past the disposal site as a fluid mud, but the discus-

sion is mostly directed at the resuspension of material instead of the fluid mud issue;

4) Values for bulk density of cores taken as long as ten weeks after disposal at the stations farthest from the disposal site proper (about 500 feet away) were statistically lower than the pre-dredge sediment in the same location by about 11% (t value = 7.38; $p<0.001$). This decrease indicates that low density materials or fluid mud were present at locations off of the disposal site. The average value for post-dredging bulk density at this station was 1.15 g/cc which is in the range of fluid mud, whereas the pre-dredging average of 1.29 g/cc was not (Barnard, 1978);

Based on the information provided, there appears to be every indication that dredged material moves off the disposal site soon after deposition. Unfortunately, the sampling was not adequate to conclusively determine the extent and fate of fluid muds. Further investigation which would provide the necessary information to control and/or avoid problems associated with fluid mud movement is recommended.

(3) **Vibrio Studies:** Results of recent Apalachicola Bay research have indicated that pathogenic bacteria inhabit the estuary's sediments (see Appendix 2). These findings have led to the funding of further research by regulatory agencies concerned with the resuspension of bacteria during dredging operations. Ingestion and concentration of high levels of suspended bacteria by oysters poses a health threat to human consumers.

The Florida Department of Natural Resources (DNR) funded a one-year survey of the sediments of East Hole, an area identified by DePaola, et al. (1984) as having higher recovery of *Vibrio cholerae* than other parts of the bay. This study was carried out in 1983 by Leslee Williams, Biology Section, Florida Department of Environmental Regulation (DER). The results indicated that vibrios were sediment-associated and that their abundance varied seasonally. Additionally, cycles of differential abundance among the individual species were identified (Williams and LaRock, 1985).

A permit request was submitted to DER in 1983 by the COE for maintenance dredging of the GIWW in Apalachicola Bay. The Department's concerns about potential public health problems related to dredging and sediment-associated bacteria led to funding by DER, Bureau of Coastal Zone Management, for additional survey work and a monitoring program (as a GIWW permit condition) funded by the COE.

The survey work consisted of two studies. One involved bacterial analysis of a series of triplicate cores taken from East Hole in March/April, and July/August. In the previous DNR study these were identified as key periods of bacterial population transition. The seasonal patterns of abundance observed in the DNR study re-occurred in this follow-up survey.

The second part of the survey was a study of core samples taken from 20 stations throughout the bay in March, just prior to GIWW dredging operations (April 1 - April 24). Cores were examined for the occurrence and distribution of *Vibrio* bacteria.

It was found that _Vibrio_ species distribution bay-wide followed similar patterns as those observed in East Hole. The predominant organisms found, and those most likely to be resuspended during subsequent dredging, were _Vibrio alginolyticus_, _V. parahemolyticus_, _V. fluvialis_, and _Aeromonas hydrophila_. In both the bay-wide and East Hole surveys it was determined that further work will be needed in order to establish what sediment characteristics and conditions support or deter occurrence of vibrios in the estuarine environment (Williams, personal communication).

The monitoring program funded by the COE was conducted in order to determine potential impacts from dredging on water quality and oysters at four sites near the GIWW: Sugar Lumps (Thigpen Bar), west of the N-S leg; the (planted shell) Jetties, east of the N-S leg; Pelican Bar and Hotel Bar, both south of the E-W leg. Surface water samples and oysters were collected over an eight week period from each site. Bacterial densities of fecal coliform bacteria, _Vibrio_ species, and _Aeromonas hydrophila_ were determined for both oyster meats and water samples. Water samples were also monitored for turbidity, total suspended solids, pH, and salinity. Dredging activities had an adverse effect on water quality for up to fifteen days after dredging. Water column turbidity and fecal coliform bacteria in both water and oysters increased at a time when COE records show a turbidity plume passing over the bar. Fecal coliform densitites were three to four times higher after dredging occurred. Dredging effects were more obvious in lower salinity areas (Sugar Lumps and the Jetties) where the dredge plume passed close to or directly over the sampling sites and less pronounced in the two southern bars which were not influenced by the turbidity plume (Williams and Eaton, in prep.). Long-term effects, monitored 30 and 60 days after dredging, reflected impacts from natural disturbances rather than dredging.

Williams and Eaton (in prep.) also measured pathogenic *Vibrio* species and *Aeromonas hydrophila*. Though values for both water column and oyster meats were higher at the southern bars, no statistical link to dredging was demonstrated. The predominant organism recovered from oysters and waters was *A. hydrophila*. Five species of *Vibrio* were recovered: *V. alginolyticus*, *V. cholerae* non-0-1, *V. fluvialis*, *V. parahemolyticus*, and *V. vulnificus*. The most frequently recovered bacteria were those which had been previously identified from the sediments as seasonally dominant: *V. parahemolyticus*, *V. alginolyticus* and *A. hydrophila*.

The extent of dredging impacts on oysters and water quality was affected by various factors, including the size and direction of the turbidity plume, salinity levels in the vicinity of the plume, and the species composition and densities of sediment-associated bacteria (Williams, personal communications).

8. Local Views on the Impacts of Dredging and Disposal

In conjunction with the preparation of a dredged material disposal plan for Apalachicola Bay, local residents were interviewed to gain a historical perspective on changes in the bay system. These interviews were conducted casually, in a question and answer format, not as a survey to be used statistically. Seventeen people of varying backgrounds and livelihoods were interviewed. Many were retired, and the most were involved in the seafood industry and had long-term, first-hand experience and knowledge of the bay.

The major ideas expressed in the interviews are presented below. This summary does not represent the opinion of every individual; many varied and contradictory views were expressed. The comments presented were the most prevalent ideas concerning dredging in general, as well as the effects of the Two Mile Channel and Sikes Cut. Within each topic, conflicting opinions are also presented. It is understood that the results of these interviews represent unsubstantiated opinions and are not necessarily correct. Nevertheless, the perspectives of local individuals are valuable in understanding the effects of the navigation projects on the bay ecosystem.

a. Dredging in General

The prevalent view was that dredging itself has not caused major problems, but disposal of the material has. The problem considered to be the most detrimental was the burial of oyster bars by mud. It was suggested that dredging should be done in winter months to avoid killing small shrimp, and to avoid such observed incidents as pumping brown shrimp out of the channel onto the flats in springtime.

It was pointed out by numerous oystermen that oysters live and thrive on certain GIWW spoil sites. Therefore, they suggested periodic shifting of disposal sites to allow the old sites to develop into oyster bars. Historically only hurricanes moved sand onto oyster bars, however, recently winter storms, such as the one in early 1983, have resulted in the burial of oyster bars. Disposal practices were considered to be responsible for this. The disposal islands at Eastpoint are believed to be migrating toward Cat Point, and burying parts of Cat Point and Bulkhead Shoals bars. It was also noted that fill-dirt placed by the Florida Department of Transportation along Highway 98 is eroded by storms and hurricanes, and then washed toward the Cat Point bar.

Other views expressed included comments that open water disposal negatively impacted the bay and all material should be placed upland, that disposal mounds both do and do not affect bay circulation, and that dredging stirs up sediments and bacteria, resulting in higher bacteria levels in oysters. It was also expressed that oysters can stand a lot of silt and that dredging won't affect them unless they are completely covered, but, covering by sand can kill oysters. Summer was believed to be the worst time for dredging, since this is when oysters are in a stressed condition.

b. Two Mile Channel

The prevalent view concerning the impact of the Two-Mile Channel on the bay ecosystem was that it resulted in freshwater being directed westward toward the Miles. This freshwater was believed to be beneficial to the oysters in St. Vincent Sound and western Apalachicola Bay. No effects from the migration of disposed material on the 80-acre lease west of Two Mile have been noticed. However, it was also stated that the Two Mile Channel and Breakwater destroyed a lot of shrimping grounds, since there used to be mud in that area.

c. **Sikes Cut Channel**

The prevalent view was that Sikes Cut has been the worst structural change in the bay. It is widely believed that before the cut, fresh river water used to enter the bay, and then travel east or west with the prevailing winds and tides. But, after the cut was constructed freshwater is now funneled out the cut into the gulf, and therefore the bay has become more saline. Changes in the salinity and currents in the bay have in turn damaged oyster bars (especially St. Vincent's Bar) and shrimping. The increased salinity in the bay is considered to be detrimental because it brings parasites and predators with it. In dry years, conchs and leeches have become increasingly bad. Saltwater also tends to bring in more trash fish. It is also believed that the cut was put in the wrong place and should have been located further west at a former natural gap so that it would not fill in so quickly. Other opinions indicated that Sikes Cut has not had a negative impact on the bay, but has brought prosperity to the big boat shrimpers, and that there has not been a freshwater oyster kill since the cut was built. It was also stated that saltwater which enters the bay does not spread out, but goes back out the cut.

d. **Jim Woodruff Dam**

Many of the people interviewed expressed a belief that the construction of Jim Woodruff Dam harmed the oyster industry because it held back water and thereby changed the salinity regime in the bay.

e. Concensus

The concensus opinion of those interviewed was that permanent changes have occurred in Apalachicola Bay, and that they significantly affect the level of productivity. There has been a general decline in fisheries landings due to Sikes Cut, Jim Woodruff Dam, and encroaching development with its associated population increase and pollution. The bay's resources are becoming over-fished due to poor resource management including lack of law enforcement, excessive number of fishermen, and a prevailing lack of conservation ethics and concern for the future.

9. Summary of Ongoing Studies and Issues

a. Navigation Maintenance Plan and COE 308 Study

There are several studies and planning efforts concerning the Apalachicola River which have a direct bearing on the Apalachicola estuary. In conjunction with the interstate study of the ACF system which was discussed earlier, the COE and the states of Alabama, Florida, and Georgia are developing a Navigation Maintenance Plan to determine what modifications, if any, are necessary and warranted to improve the availability of the navigation channel on the Apalachicola River. The plan is expected to be adopted in Fall, 1986. What is ultimately approved in this plan will significantly affect how the navigation project on the Apalachicola River will develop in the future. The major principles upon which this plan is being developed are 1) to have no future net degradation of environmental quality in the basin from the navigation project, and 2) to acknowledge the limitations on channel availability from upstream discharges.

In conjunction with the interstate study, the COE in coordination with the States of Florida, Georgia and Alabama is conducting a 308 Study on the ACF basin. The purpose of this study is to develop solutions to various water resource problems which have either resulted in, or have the potential to cause, conflicts over the multiple use of the basin's water resources. Specifically, a long range water budget and water management strategy will be developed to enable the states to coordinate the management of the basin's water resources in concert with the appropriate federal agencies. In developing the overall management strategy drought management needs, and problems relating to navigation, water supply, flood control, recreation, hydropower, and fish and wildlife will be considered (COE, 1984).

As part of this study the COE plans to evaluate the seasonal water needs (quantity and quality) of Apalachicola Bay. This evaluation is to be done by an interagency workgroup and is intended to be a preliminary evaluation. The principal objectives of this effort are to provide resource managers a general perspective of the issue and to provide some direction and definition for further research efforts. The approach will be to estimate the salinity gradients in the estuary in selected low-flow and drought discharges using the recently developed hydrodynamic model of the estuary. Then, based on an understanding of how salinity affects selected key species in the estuary, the impacts of the prolonged low flow and drought discharges on the ecology of the estuary will be estimated.

b. Sedimentation Rates in the Bay

A study has been funded by the Apalachicola National Estuarine Sanctuary to evaluate sediment loading processes in the northern fringes of the estuary. This study is based upon measurements of suspended sediment levels and sediment core analysis. Sediment cores are being analyzed using standard radiometric dating methods (i.e., lead-210, and radiocesium), magnetic susceptibility and quantitative clay mineralogy data to gauge the rates at which suspended sediment is being deposited on the bay floor. Preliminary results indicate a high rate of sediment deposition (over 10 mm/year) which is similar to the bathymetric differencing values obtained by Isphording (1985). Isphording calculated an average rate of 1.31 mm/year for East Bay, 2,87 mm/year for Apalachicola Bay, 17.2 mm/year for St. George Sound and 0.37 mm/year for St. Vincent Sound. The area-weighted average for the entire bay system was 6.73 mm/year. The study discussed above is scheduled to be completed by December, 1986.

c. Sikes Cut Study

As discussed in Section III(D) of this report, Sikes Cut, or St. George Island Channel, is a 10 x 100 foot channel which extends from a ten foot depth in Apalachicola Bay, across St. George Island, to a ten foot depth in the Gulf of Mexico. The channel was originally cut in 1954. Considerable controversy has surrounded the question of whether the cut has had a major influence on the estuarine ecosystem. As discussed earlier, many local fishermen have expressed a belief that oyster productivity has decreased in the western areas of the bay, and attribute this decrease to Sikes Cut which allows more saline water into the bay and more freshwater out of the bay. This increase in salinity is important because it brings with it predators and parasites that are detrimental to the bay's oyster populations. The southern oyster drill and the stone crab are two of the most damaging oyster predators in the bay, and both are intolerant of low salinities (Menzel, et al., 1958; 1966).

The bar which is believed to be most damaged by the cut from the perspective of local opinion is St. Vincent's Bar. Swift (1898) reported dense growth of oysters on this bar in his survey of 1895-1896. However, Danglade (1917) noted that St. Vincent's Bar was showing signs of depletion and had been closed by the State to recover. During the investigations of Pearse and Wharton (1938) there was an indication that St. Vincent's Bar was still productive, but later Ingle and Dawson (1953) noted no oyster production on the bar. Menzel, et al. (1958) studied the causes of oyster depletion in the bar and found abundant spatfall, but high oyster mortality there. They concluded that predation, especially by drills and stone crabs, was the primary cause of mortality. Establishment of predators on the reef was believed to be due to four or five years of low rainfall, and they predicted that with increased rainfall the reef might recover. Since the 1950's, however, the reef has not recovered (Miley, personal communication).

Several hydrographic studies have assumed that Sikes Cut has minimal impact on current structures in the bay at large (Gorsline, 1963; Vansant, 1980). Mehta and Zeh (1980) evaluated the distribution of tidal influences from Sikes Cut on Apalachicola Bay and found that "the boundaries of the ebb flow differ from those of the jet (flood flow) so that the volume of water that enters the inlet has a different identity, at least partially, from the volume that issues from the inlet during flood (ebb?)". However, this different identity is overlooked in developing their conclusions. Saline water which enters the inlet during flood flow and is not removed during ebb flow can result in a net influx of salt into the estuary. Preliminary evaluations indicate that Sikes Cut has led to a net influx of salt over a tidal cycle during low-flow periods. However, this issue needs to be evaluated in greater depth.

The question of whether this potential net introduction leads to an accumulation of higher salinity water in the estuary, and if so, at what river discharge levels the accumulation is ecologically significant, have never been evaluated. Negative effects would be expected to be greatest during periods of low river flow and decreased bay mixing in the summer months, which is also a time of stress for oysters. Low river flows can persist for several months so that salinity accumulation could occur over many consecutive tidal cycles. It is the long-term, chronic elevation of salinity from a series of tidal cycles that can cause a sustained or detrimental impact, not the effects of single tidal cycle. Neither Mehta and Zeh (1980) or COE (1985) considered these cumulative effects. Field surveys conducted by Livingston (1984) suggest that the area affected by increased bottom salinities due to Sikes Cut are greater than that predicted by Mehta and Zeh (1980) and COE (1985).

The hypothesis in Mehta and Zeh (1980) that Jim Woodruff Dam has reduced peak discharges in the river and subsequently caused an increase in salinity throughout the bay is based on information from Boynton (1975). Recent analyses of the impact of Jim Woodruff Dam on stream flow of the Apalachicola River have shown that since its construction, the dam has had minimal impact on the distribution of streamflow over the year (Maristany, 1981; Leitman, et al., 1983). Because Jim Woodruff Dam is a run-of-the-river type dam it has very limited capabilities to store water and has minimal effects on flood peaks of the river, contrary to the contentions in Boynton (1975). The dam does have the ability to significantly impact flow over the short-term, especially at low flows. However, at low-flow the reservoirs are operated to augment flow in the river to enhance navigability; therefore, their effect would be to decrease, not increase salinities in the estuary.

FDER (1984) and Alabama, et al. (1984) also evaluated the impact of the entire reservoir system on the Apalachicola-Chattahoochee-Flint River system on flows in the Apalachicola River. Both studies noted that comparison of flow-duration curves before and after reservoir construction indicate that there has been an overall increase in flow durations at the Chattahoochee, Florida recording gage, and that this increase is attributable to both upstream impoundments and increased rainfall in the basin.

In summation, the hypothesis in Mehta and Zeh (1980) that the dam is responsible for changing the salinity regime in the bay does not appear supportable.

It has also been contended by local fishing interests that existence of the cut provides an outlet to release flood water from the river and thereby reduces the possibility of oyster mortality from large floods which can lower salinities throughout the estuary. This type of damage to the oyster beds from extreme freshwater flows, or freshets, has been noted by both Swift (1898) and Danglade (1917). No evaluations have been done in regard to the effects of Sikes Cut on the estuary at high river flows.

There has been some speculation that the north-south leg of the GIWW plays a role in the distribution of fresh water in the bay. A local theory suggests that this deepened channel shunts the river water in a straight line and directs it toward and out Sikes Cut. This diversion therefore lessens the length of time the freshwater remains in the bay, and thereby affects salinity and oyster production. There is no data to support this theory and none of the numerous studies carried out over the years have observed any phenomenon such as a distintive fresh water flow limited to the GIWW channel or its immediate vicinity.

Because of long-standing questions regarding the impact of Sike's Cut on the estuary, considerations to stabilize the inlet by extending the rock jetties through the land cut, and the fact that the COE intends to apply for a maintenance dredging permit for the Apalachicola Bay projects; a study effort was initiated in late 1985 to determine the effects of Sikes Cut on the estuary.

This study effort involves the COE, DER, and outside consultants representing the fields of general ecology, physical oceanography, biological oceanography, and oysters. Existing data and studies are being utilized, as well as the hydrodynamic model recently developed for the COE, to estimate the impacts from the cut on the estuary. Preliminary results from the model runs indicate that under certain conditions (e.g., low flow and south wind) Sikes Cut has a significant impact upon salinity distribution within the bay (Raney and Jin, 1986; Raney and Jin, 1986a). The study is scheduled to be completed in late spring, 1986.

d. Timing of Dredging

Aquatic organisms use estuaries for different purposes such as breeding grounds, nursery areas, or home territories (Morton, 1977). While most year-round residents can tolerate wide ranges in salinity, temperature, turbidity, and suspended solids, many migratory species and larval forms cannot. Whether for physiological (salinity, turbidity, or temperature tolerances), reproductive (mating or spawning), or growth (feeding or safety) related reasons, many species of organisms migrate in and out of estuaries during different seasons. Variation in the ability to tolerate or avoid stressful conditions by different species and individuals at different stages in their life cycle makes the timing of dredge and disposal activities important.

Most commercially important species in the bay migrate during some period of their life cycle. Table 12 lists some of the more important species along with their characteristic movements. Many of the migrating species (shrimp, blue crab, mullet, and

TABLE 12

SEASONALITY OF IMPORTANT APALACHICOLA BAY SPECIES

Oyster	Year-round residents. Most spawning and spatfall occurs from April to November with a mass spawning peak in May. Can spawn year-round.
Blue Crab	Adults present most of year with peak numbers in May and June. Females move offshore and spawn in spring and summer. Juveniles migrate into the bay from November to April.
Shrimp	
White	Migrate offshore to spawn in winter. Juveniles migrate in spring and summer. Some overwinter in deep holes.
Pink	Juveniles migrate to estuary in summer and fall.
Brown	Juveniles migrate to estuary in late winter, early spring; peak in spring-summer. Adults migrate offshore late summer.
Anchovy	Year-round residents. Spawn from spring to fall with a peak in May. Highest population in summer and fall, lowest in winter.
Mullet	Migrate and spawn offshore October to February. Highest population in bay in summer and fall. Many young overwinter in deep holes.
Southern Flounder	Present year-round. Many migrate offshore to spawn in winter. Juveniles arrive in bay in spring and summer.
Gulf Flounder	Migrate offshore in winter. Juveniles return in February through April.
Croaker	Adults migrate offshore summer to fall. Juveniles return in October. Juveniles remain in bay their first summer and migrate offshore in winter.
Spot	Juveniles and adults migrate offshore from late summer to winter and return in late winter, early spring. Post-larvae return in January.

flounder) leave the bay with the onset of cold weather and move offshore to warmer, more saline gulf waters to feed, spawn, or mate. Other species remain in the bay, burrowed in the sediment or staying in deeper waters to avoid low temperatures and salinities. Many of these migrating species return to the bay from early spring until summer in their juvenile forms and use the estuary as a nursery ground. Additionally, year-round residents may also spawn during this season. As noted earlier, the marsh systems along the bay side of St. George Island, the bayous and creeks of St. Vincent Island, and the extensive marshes surrounding East Bay are major areas where post-larvae and juveniles of many species congregate (Livingston, 1984).

In general, the winter in Apalachicola Bay is characterized by low salinities (due to high river flow), low temperatures, and high turbidity and suspended sediment loads. In contrast, summer in Apalachicola Bay is generally characterized by higher temperatures, higher salinities, lower turbidities, and more available food. During the summer, storms can cause bottom disturbances and therefore temporarily increase turbidity levels. Nevertheless, from a physical perspective, high turbidity generated by dredging is more consistent with the prevalent natural conditions in the winter.

The previous discussion and Table 12 indicate that the potential for damage to bay fauna from dredge and disposal activities is greatest during the spawning and juvenile times. Turbidity has been shown to disrupt larval development in many species. Benthos spawning and larval settlement could be seriously attenuated by untimely deposition at disposal sites and surrounding areas. Bay-wide migrations of certain species could also be disturbed by a dredge and disposal operation. Conversely, since most species are in their more quiescent life stages, winter dredging would not only be less disruptive, but would also allow for more rapid recovery and recolonization of disturbed habitat in the spring. It should be noted that winter dredging might disrupt species that take refuge from low temperatures and salinities in the channels and deep areas of the bay. Though this matter needs further documentation, it appears that the advantages of winter dredging far outweigh this disadvantage.

COE (1974), WAR (1975), COE (1982), Livingston (1984a), and local fishermen all suggest that dredging be restricted to winter and early spring months to minimize impacts on the ecosystem. The recent permit for the GIWW acknowledged this concern and restricted dredging and open-water disposal to December through March.

C. Summary of Impacts on the Apalachicola Estuary

As indicated earlier, a considerable body of knowledge exists on how dredging and disposal practices impact estuaries in general. And, considerable effort has been expended to understand the impacts of dredging and disposal practices on the Apalachicola estuary. A detailed review of these data, however, seems to give a better perspective on the difficulties of monitoring, evaluating, and assessing impacts within estuaries than on the impacts themselves. By nature, estuaries are complex, dynamic systems which are not completely understood by man. Activities with gross impacts and/or whose impacts manifest themselves over a short period of time are more easily discernible. However, activities which have more subtle effects that may prove to have far reaching impacts over time, such as a gradual shift in community structure, are not so easily identified. Because a specific impact has not been noticed, or related to a specific activity, does not mean it is not occurring. This section shows that few ecological impacts on the Apalachicola estuary have been clearly demonstrated. Nevertheless, it is clear that some degree of habitat and community disruption has occurred. However, the studies addressing these impacts have been inadequate to define either the areal or temporal extent of disruption. Because of these difficulties and because of the economic importance of the Apalachicola estuary, project staff believe a constant vigil should be kept on this ecosystem.

The areal extent of impacts from dredge and disposal activities is highly variable and dependent upon conditions in the bay and which parameters are affected. If maintenance activities affect circulation patterns and/or salinity flux, the potential for a subtle, widespread impact exists. On the other hand, if the effects are limited to burial of habitat or changes in water quality parameters, the impacts may be more localized.

1. Physical Impacts

The most obvious physical impacts of dredge and disposal activities in Apalachicola Bay are the relatively short-term increases in turbidity and suspended solids, and the long-term establishment of dredged channels and elevated disposal sites. Fluid mud flow and the continued resuspension of dredged material by wind generated waves and currents are impacts that are less obvious and less studied.

Turbidity plumes observed in Apalachicola Bay vary in size and persistence depending upon factors such as density and grain-size of material being dredged, wind speed and direction, current speed and direction, tidal phase, and type of disposal pipe configuration. The degree of stratification of the water column also influences the turbidity plume (COE, 1984). Plume sizes observed in the bay have been estimated at: 1500 feet wide and 3500 feet long (WAR, 1975); 4000 feet in length (COE, 1984); and 1.3 miles in length and covering a maximum areal extent of 100 acres (Schubel, et al., 1978). All three studies found that the plumes have much higher concentrations of suspended solids and turbidity near the bottom than at the surface of the water column. Their dimensions are also much larger near the bottom.

Within the plume, turbidities and suspended solid concentrations are highest at the point of discharge and decrease with distance from the discharge. Concentrations of suspended solids have been measured as high as 130 g/l (Ryan, et al., (in prep.) and turbidities of 3220 FTU by WAR (1975). Only one study, WAR (1975), addressed the persistence of the plume and found most plumes were visible for only a few hours. COE (1984) found that the plumes are not restricted to the disposal areas but also cross the channel and extend into non-disposal areas.

While few long-term impacts have been found in the water column due to turbidity plumes, studies currently underway indicate that secondary and tertiary resuspension of the dredged material by wind is more persistent and extensive than the initial plume (Ryan, et al., in prep.).

Only about 1-3% of the discharged material is incorporated into initial turbidity plumes (Schubel, et al., 1978). The remaining 97-99% settles rapidly to the bottom, some of which may develop into a fluid mud layer. One fluid mud study has been carried out in Apalachicola Bay under contract to COE. Preliminary data from this study (USGS, 1984) suggests that the dredged material initially spreads out in a layer up to one foot thick and is then shifted around over time. The material is not contained within the disposal areas (USGS, 1984), but covers a wider area. The COE depends on this migration of material off of the disposal sites to rejuvenate the site and extend its project life (COE, 1981; COE, 1982).

Dredge and disposal activities appear to have affected the sediment characteristics in some parts of the bay. This change apparently is caused by continued resuspension of the finer sediments over disposal areas which causes a sorting phenomenon. The dredged channels generally have more silt associated with them than the rest of the bay (WAR, 1975; Taylor, 1978; Livingston, 1983a). The only channel for which sediment samples were available for the same site over time was Eastpoint Channel, and the grain-size distribution data from this channel showed sediments getting finer over time. Sediments in the disposal areas are more sandy, or coarser, than surrounding areas (WAR, 1975; Taylor, 1978) due to the finer sediments being continually resuspended and either deposited in channels, distributed over the bay, or carried out the passes. The surface sediments gradually revert back to a finer composition as distance from the disposal areas increases (WAR, 1975).

Dredge and disposal activities also directly impact the bathymetry of the bay reducing depth in disposal areas and increasing depth in channels. Preliminary data from COE bathymetric charts (COE, 1984a) indicate the shifting of sediments can continue for a period of time, during which time channels fill in and disposal areas lose sediments. Changes in bathymetry have the potential to affect circulation patterns in the bay, and subsequently have a widespread impact on the estuary. Circulation changes have neither been documented or thoroughly evaluated in Apalachicola Bay.

2. Chemical Impacts

Dredge and disposal activities have impacted the chemical constituents in the water column and sediment layers of Apalachicola Bay. Because the water column and sediment layers of the estuary are in a relatively unpolluted state these impacts have not caused serious problems. Schubel, et al. (1978) noted dissolved oxygen depressions from 0.2 to 1.8 mg/l at the surface and 0.2 to 6.0 mg/l near the bottom during dredge and disposal activities. The areas affected by the oxygen sags were generally small, usually less than 125 acres. The oxygen depressions occurred in the disposal plume, and the authors concluded that they were largely due to the oxidation of dissolved constituents from interstitial waters and also possible oxidation of the sufaces of sulfide minerals.

Increased concentrations of the ammonium ion (NH_4^+) and reactive silicate ($Si(OH)_4$) in the water column have been documented during dredging activities by Schubel, et al. (1978) and Ryan, et al. (in prep.). No significant increases in other nutrient concentrations have been found in the water column. Ryan, et al. (in prep.) however, noted extremely high concentrations of ammonia in the fluid mud layer created by disposal activities. Ammonia can be extremely toxic in its un-ionized form (NH_3). The ratio of un-ionized ammonia to total ammonium (NH_4^+) is related to salinity, temperature, and pH. Depending upon the conditions present at the time of dredging, high concentrations of un-ionized ammonia (NH_3) can kill benthic organisms which come in contact with the fluid mud layer. The potenital for harm is currently being investigated further by DER.

No significant changes in metal concentrations in the sediment or water column have been detected either during or after dredging activities by WAR (1975) and Schubel, et al. (1978). Ryan, et al. (in prep.) however, found high concentrations of arsenic, copper, and chromium in the sediments when compared to other bays in the state. When the data are compared using metal-to-aluminum ratios from natural sources, the authors did find that sediments in the dredged navigation channels were enriched with cadmium which did not originate from natural sources. The source of this metal is also being investigated further. Livingston (1984a) notes that the dredged channels of the GIWW, Two Mile, and Eastpoint are depositories of silt-laden sediment contaminated with heavy metals. The validity reliability, and usefulness of the elutriate test, used extensively in dredge and disposal studies has been questioned by Schubel, et al. (1978) and Ryan, et al. (in prep.) after studies in Apalachicola Bay. The elutriate test, a lab test which supposedly measures the concentration of metals available for resuspension from the sediment, has been questioned because it does not simulate the physiochemical make-up of the disposal site. If the elutriate test is not valid, studies which have found low concentrations of metals and or nutrients available for release may not be applicable to natural conditions in the bay.

3. Biological Impacts

As indicated in the general biological impacts section of this document, biological impacts from dredging and disposal are difficult to assess. A vast number of variables and their interactions and synergistic relationships affect the life and well-being of aquatic organisms, especially in estuaries. To single out the effects of any one of these variables, unless it is catastrophic, is often conjectural, and therefore, open to severe criticism. Likewise, assuming that undefined impacts are not important or nonexistant is also faulty. Therefore, in addition to presenting documented biological impacts in Apalachicola Bay, this section will also address possible or probable impacts.

Certainly the most pronounced biological impact is the disruption of the benthic habitat and community in the channel during dredging, and the burial of the benthos during deposition at the disposal site. Since the dredged part of the channel represents such a small portion of the bay (i.e. less than 1% of the bottom area) and since studies show some degree of recovery of benthic organisms in the channel (WAR, 1975; Taylor, 1978), the concerns here would chiefly be: 1) that commercially important species such as the juvenile shrimp and blue crabs which live in the channels in the winter might be sucked up during dredging activities; and 2) that benthic infauna might serve as an initial link in a metals or organics bioaccumulation food chain. Careful timing and execution of the dredging process would likely avoid the former problem. There seems to be a concensus that winter dredging would have the least chance of disrupting fauna both within the channels and throughout the bay. Although Eastpoint, Two Mile, and the GIWW Channels have been shown to have higher than background metals concentrations (Livingston, 1984a), no studies have been done to show whether any of the species residing in the channels are actually incorporating these pollutants into their tissues. Olsen (1982) indicates that bioaccummulation from contaminated sediments can occur, but it is highly species specific and pollutant specific. Although, it is doubtful that bioaccumulation is presently a problem in Apalachicola Bay, there is the possibility that as usage of the bay increases in the future, sediment contamination will also increase.

Habitat burial at disposal sites definitely occurs. The total area affected, and the rate and degree of recovery of these areas is not completely understood. Benthos at the disposal site is normally buried 5-8 inches by the disposal material (WAR, 1975). There is some laboratory evidence (Olsen, 1982) that a few species can migrate this distance, but most organisms probably suffocate. No macroinvertebrate samples have been collected on or around disposal sites close to the time of dredging. However, oystermen report oysters are sometimes buried in areas near to dredging operations. One study on oyster bacteria also reports such burial (Williams and Eaton, in prep.). However, it should also be noted that sometime after deposition, the disposal mounds serve as new substrate for development of oyster bars.

There is indication that some amount of dredged material either in the form of fluid mud or suspended fine sediment spreads out over a larger area (WAR, 1975; USGS, 1984). One imagines a gradation of decreasing depth and density of dredged materials away from the actual site, but the spatial and temporal extent of this surface 'floc' and its effect on benthic flora and fauna near the time of dredging is still not completely clear. The areas most susceptable to fluid mud or resuspension of surface materials are those with high percentages of fine-grained silts and clays (Schubel, et al., 1978). In Apalachicola Bay, the Eastpoint area is most likely to present fluid mud problems, not only because of the fine-grained nature of its disposal materials, but also because of its proximity to the productive oyster bars at Cat

Point. Because of GIWW sediment characteristics and the orientation of the disposal sites on the N-S leg of the GIWW with respect to the dominant current patterns in the bay, migration problems might also occur here.

Data on the recovery of the benthos at disposal sites is limited. WAR (1975) collected one set of benthic samples about 4 1/2 months after dredging on both the disposal site and other stations located around the bay. The data indicate that the benthos shows some degree of recovery. However, the recovery is demonstrated only in density and the Shannon-Weaver diversity index, parameters which by themeselves are generally accepted as being of little use in describing community dynamics and/or impacts (i.e. extreme low values can indicate environmental stress but the reverse is generally meaningless without significant additional information). Little information and no discussion of the actual community structure is given. A shift in the community at this low trophic level could have substantial effects on the ecology of the estuary. In addition, the increases in density and diversity found in WAR (1975) strongly reflect seasonality as well as recovery. It should be noted that in this study, the only station that was on a disposal site actually used and that had before and after samples showed the least increase in density and diversity, a fact that might indicate a dredging impact.

Taylor (1978) sampled disposal sites about one year after dredging and found no significant effects of dredging on density and diversity parameters. Again, actual community descriptions and structure were largely ignored so again the rate and extent of the recovery is questionable. WAR (1975) and Livingston (1984a) have also investigated impact on benthic macroinvertebrates throughout the bay and were unable to define any effects due to dredging and disposal. Against the backdrop of such high variability and within the studies' design and scope restraints, only catastrophic impacts would be likely to be documented.

Changes in hydrology of the bay due to the creation of channels and disposal mounds would, of course, affect biological parameters. Livingston (1984a) contends that salinity has changed because of dredging at Sikes Cut, and that there has been a concomitant change in biological parameters in that area. These changes are still undocumented. The ongoing Sikes Cut Study should clarify some of these concerns.

Besides concern about bioaccumulation and benthic community impacts, questions have also been raised about possible public health hazards in the form of increased levels of pathogenic bacteria and viruses which may be stirred up from the sediments of Apalachicola Bay by dredging and disposal activities. WAR (1975) measured coliform bacteria (a group of non-disease causing, predominatly freshwater associated species) in water and sediments before, during, and after dredging. Values were low for sediments and mostly low for water samples with the exception of one sample from the discharge. Williams and Eaton (in prep.) found water column turbidity, and both water column and oyster meats fecal coliform counts, elevated at a time when COE records show a turbidity plume passing over the bar. Williams and Eaton (in prep.) also measured pathogenic *Vibrio* species and *Aeromonas hydrophila*, but no statistical link to dredging was demonstrated.

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APPENDIX 1

Common and Scientific Names for Species Mentioned

Vegetation:

Needlerush	*Juncus spp.*
Smooth cordgrass	*Spartina alterniflora*
Saltmeadow cordgrass	*S. patens*
Eurasian watermilfoil	*Myriophyllum spicatum*
Shoal grass	*Halodule wrightii*
Manatee grass	*Syringodium filiforme*
Turtle grass	*Thalassia testudinum*
Tape grass	*Vallisneria americana*
Widgeon grass	*Ruppia maritima*
Sago pondweed	*Pomatogeton spp.*
Cattail	*Typha domingensis*
Bullrush	*Scirpus spp.*
Sawgrass	*Cladium jamaicense*

Trees:

Water tupelo	*Nyssa aquatica*
Ogeechee tupelo	*N. ogeche*
Bald cypress	*Taxodium distichum*
Carolina ash	*Fraxinus caroliniana*
Green ash	*F. pennsylvanca*
Sweetgum	*Liquidambar styraciflua*
Overcup oak	*Quercus lyrata*
Water hickory	*Carya aquatica*

Benthic Macroinvertebrates:

Snail	*Neritina reclivata*
American oyster	*Crassotrea virginica*
Southern oyster drill	*Thais haemastoma*
Stone crab	*Menippe mercenaria*
Blue crab	*Callinectes sapidus*
Crown conch	*Melongena corona*
Whelk	*Busycon contrarium*
White shrimp	*Penaeus setiferus*
Pink shrimp	*P. duorarum*
Brown shrimp	*P. aztecus*

Fish:

Bay anchovy	*Anchoa mitchilli*
Skillettfish	*Gobiesox strumosus*
Goby	*Gobiosoma spp.*
Croaker	*Micropogon undulatus*
Menhaden	*Brevoortia patronus*
Spot	*Leiostomus xanthurus*
Silver perch	*Bairdiella chrysoura*
Speckled trout	*Cynoscion nebulosus*
Skipjack herring	*Alosa chrysochloris*
American eel	*Anguilla rostrata*
Hogchoker	*Trinectes maculatus*
Largemouth bass	*Micropterus salmoides*
Spotted gar	*Lepisosteus oculatus*
Long-nose gar	*L. osseus*
Mullet	*Mugil cephalus*
Flounder	*Pralichthys spp.*

Red drum (redfish)	_Sciaenops ocellatus_
Cobia	_Rachycentron candadum_
Bluefish	_Pomatomus saltatrix_
Red snapper	_Lutjanus campechanus_
Sand seatrout	_Cynoscion arenarius_
Alabama shad	_Alosa alabamae_
Atlantic sturgeon	_Acipenser oxyrhynchus_
Atlantic needlefish	_Strongylura marina_
Striped bass	_Morone saxatilis_
Mountain mullet	_Agonostomus monticola_
Bluegill	_Lepomis macrochirus_
Redear sunfish	_Lepomis microlophus_
Common carp	_Cyprinus carpio_
Mosquito fish	_Gambusia affinis_
Reptiles:	
American alligator	_Alligator mississipiensis_
Saltmarsh water snake	_Natrix faciata_
Diamond back terrapin	_Malaclemys terrapin_
Glass lizard	_Ophisaurus compressus_
Loggerhead sea turtle	_Caretta caretta_
Birds:	
Osprey	_Pandion haliactus_
Bald eagle	_Haliaetus leucocephalus_
Brown pelican	_Pelecanus accedentalis_
Least tern	_Sterna atrillarum_
Laughing gull	_Larus attricilla_
Black skimmer	_Rynchops niger_

Royal tern	*Sterna maxima*
Mammals:	
White-tailed deer	*Odocoileus virginianus*
Hog	*Sus scrofa*
Fox squirrel	*Sciuris niger*
Grey squirrel	*S. carolinensis*
Black deer	*Ursus americanus*
Raccoon	*Procyon lotor*
Opossum	*Didelphis virginiana*
Marsh rabbit	*Sylvilagus palustris*
Rat	*Scalopus asquaticus*
Round-tailed muskrat	*Neofiber alleni*
Otter	*Lutra canadensis*
Cotton rat	*Peromyscus gossypinus*
Striped skunk	*Mephitis mephitis*
Sambar deer	*Cervus unicolor*

APPENDIX 2

Microorganisms of Public Health Concern

1. Microorganisms from External Sources

Apalachicola Bay has numerous known external sources of pollution. River water and overland runoff bring domestic sewage pollution from Apalachicola's many septic tanks and its sewage treatment plant into the bay. Wastes from wild and domestic animals, by-products from fish and oyster processing houses, and discharges from fishing boats, pleasure boats, and commercial shipping vessels also enter bay water to varying degrees. These sources of pollution usually contain high levels of fecal coliform bacteria. Regulatory agencies (such as the Department of Natural Resources and the Food and Drug Administration) use fecal coliforms as indicator organisms to classify shellfish harvesting waters and determine shellfish quality. Shellfish such as oysters are filter-feeders and are known to concentrate microorganisms of all kinds from the surrounding water, including bacterial and viral pathogens. Because oysters are eaten raw, there is concern for their potential to make people ill, since microbial loads in oysters may multiply rapidly under various processing and storage circumstances (Hood, et al., 1983a).

Standards using fecal coliforms as indicator organisms for water quality in shellfish harvesting areas have been set by the Interstate Shellfish Sanitation Program (in which the Florida Department of Natural Resources, the U.S. Food and Drug Administrative and the shellfish industry participate). Upper limits are 14 MPN (most probable number) per 100 ml water, and MPN levels at specific locations may not exceed 43 MPN/100 ml water more than 10% of the time (Thompson, et al., 1984). DNR divides shellfish harvesting areas into Approved, Conditionally Approved, or Prohibited areas based on these standards for water and knowledge of the sources, dilution, die-off, and dispersal of fecal coliform bacteria (Figure 12). Formerly, when samples from Approved or Conditionally Approved waters exceeded the acceptable standards for bacteria, these areas would be closed to shellfish harvesting until bacterial levels subsided to acceptable levels. Recently, a new management plan was developed and implemented for closure of the bay (Thompson, et al , 1984). A correlation exists between the rise in river-stage and/or rainfall and elevation of fecal coliform concentrations in Apalachicola Bay. The plan's basic assumption is that coliform levels can be predicted based on river-stage and rainfall levels.

There are problems involved with using fecal coliforms as indicator organisms for water quality. The coliform group correlates well with freshwater, becoming debilitated in salty water, and is therefore not the best pollution indicator in estuaries (L. Williams, personal communication). Several studies have shown no correlation between fecal coliform levels and levels of enteric viruses and potentially pathogenic bacteria which are natural residents in aquatic systems (Musselman and Carr, 1982; Hood, et al., 1983b). It also takes a long time (24 hours) to process water samples for presence of fecal coliforms, which is a source of contention between the oystermen and DNR when it comes to speed of re-opening the bay after closure due to river-stage and rainfall. Attempts to find an associated organism to replace fecal coliforms as an indicator have not yet been successful, and fecal coliforms remain the most acceptable determinant of potential health problems at this time (Hood, et al., 1983b).

Enteroviruses commonly found in sewage effluent are known to adsorb to estuarine sediments and survive longer than in estuarine water alone (Smith, et al., 1978). Such viruses include echovirus, coxsackie virus, and poliovirus. These enteroviruses, as well as reoviruses, adenoviruses, and hepatitus A virus, are considered prime candidates for shellfish contamination, and viral epidemics attributed to shellfish ingestion most frequently involve a hepatitus virus (Ellender, et al., 1980). As yet, no research has been done on the presence or abundance of viruses in Apalachicola Bay water, sediments, or oysters.

2. <u>Microorganisms from Sources Within the Bay</u>

Another very important group of microorganisms of public health concern are the <u>Vibrio</u> bacteria. They have been found in the estuarine sediments, shellfish, and waters of Apalachicola Bay, and numerous other gulf estuaries, and Chesapeake Bay (Hood, et al., 1983c; DePaola, et al., 1984; Williams and Larock, 1985). These vibrios are believed to originate within the estuary because no correlations have been made between the occurrence of vibrios and the presence of fecal coliform bacteria (known to be introduced from sources external to estuaries (Hood, et al., 1983a)). In Apalachicola Bay, Musselman and Carr (1982) found that *Vibrio* species were not coming from the same sources as fecal coliform bacteria, being found in areas remote from any discharges of domestic sewage.

Six types of *Vibrio* species have been isolated from Apalachicola Bay, and have been found throughout the estuary in waters, sediments and/or shellfish; each is capable of causing illness in humans (Blake and Rodrick, 1983; Hood et al., 1981, 1983c; Williams and Larock, 1985):

1) *Vibrio alginolyticus* can cause wound infections.
2) *Vibrio cholerae* 01 is responsible for the major cholera outbreaks worldwide. It causes severe gastroenteritis and may result in death.
3) *Vibrio cholerae* non-01 is the most prevalent *Vibrio* organism in Apalachicola Bay, and also causes severe gastroenteritis.
4) *Vibrio fluvialis* causes gastroenteritis.
5) *Vibrio parahaemolyticus* causes gastroenteritis and wound infection.
6) *Vibrio vulnificus* may cause wound infection, septicemia (a severe blood infection), and gastroenteritis.

Numerous outbreaks of cholera have occurred along the Gulf Coast since the late seventies, and most cases have been traced back to the consumption of raw shellfish (primarily oysters, and some improperly cooked blue crabs) (Hood, et al., 1983c). In Florida between 1979 and 1983, there were thirty-four reported cases of gastroenteritis due to _Vibrio_ species. Two of these cases, due to _V. vulnificus_, resulted in fatalities in patients over sixty years old. Thirty out of thirty-two of the cases with known food histories had eaten raw oysters before becoming ill, and the source of most of these oysters was Apalachicola Bay. Additionally, eighteen cases of blood or wound infection due to _Vibrio_ species were reported; these were related to exposure to seawater.

Because of the great potential for serious health problems due to consumption of raw shellfish, and because Apalachicola Bay produces nearly 90% of Florida's oysters, numerous microbiological investigations have been conducted and are ongoing in Apalachicola Bay. In 1980, oysters harvested from approved shellfish harvesting waters were found to contain _V. cholerae_ non-01 (Hood, et al., 1981). In an experimental study, _V. cholerae_ was found to grow in estuarine waters and sediments from Apalachicola Bay, with best growth occurring in salinity levels between 10 to 25 ppt. Additionally, _V. cholerae_ was observed to attach readily to chitin (Ness, et al., 1981). Another study which sampled 24 stations around the bay found _V. cholerae_ 01 and non-01 in both polluted waters (Scipio Creek) and non-polluted waters (East Hole) (Motes, et al., 1983). In other research, a series of organisms (including oysters, blue crabs, mussels, plankton, and algae) and sediment and water samples from Apalachicola Bay and Tampa Bay were tested for the presence of _V. cholerae_ (Hood, et al., 1983c). _V. cholerae_ non-01 was found in 45% of all oysters sampled, 30% of all sediments, 50% of water samples and 75% of all blue crabs. No *V. cholerae* was found in mussels, plankton, or algae. Only one oyster sample contained *V. cholerae* 01; it was from St. Vincent Sound, an approved shellfish harvesting area. Between August and November, at salinity levels of 12 to 25 ppt and at temperatures between 20 and 35°C, *V. cholerae* were most abundant (Hood, et al., 1983c). The seasonal occurrance of six *Vibrio* species and *Aeromonas hydrophila* (another bacterium originating within the bay and one which also causes gastroenteritis) in Apalachicola Bay sediments has been investigated (L. Williams, personal communication). A succession of species occurred over the year, apparently related to temperature changes. The species occurred most commonly in sandy sediments at depths of one inch or less and in a surface floc, and one species was recovered from a depth of six inches. Results are pending from a bay-wide core survey of 20 stations examining the seasonal and areal distribution and depth occurrence of *Vibrio* species, and their relation to water quality parameters and sediment type (L. Williams, personal communication).

An unrelated study may have research implications for Apalachicola Bay. In a cholera-endemic region of rural Bangladesh, India, virulent *V. cholerae* in surface water contaminated by cholera victims were found to concentrate on the surface of water hyacinth, *Eichornia crassipes*, and the authors suggested that these floating plants may serve as environmental reservoirs for cholera during the inter-epidemic period (Spira, et al., 1981). Water hyacinths are abundant in the Apalachicola area, found in the freshwater streams entering the main river, including Scipio Creek where presently the local sewage treatment plant outfall is located. When river flows are high in the area, large masses of floating water hyacinth are transported into the bay. Although no known cholera problem exists in the city of Apalachicola, the investigation of water hyacinth as a possible transporter of bacteria may be warranted, to see if it plays some role in the distribution of *Vibrio* species in the bay.

APPENDIX 3

Review of Important Fish Species in Apalachicola Bay

1. Bay Anchovy

The most abundant trawl-susceptible fish of Apalachicola Bay is the bay anchovy, *Anchoa mitchilli*, yet it is not harvested commercially. It is a small, pelagic, schooling species found throughout the bay, and has made up over 40% of the total fish catch in the long-term trawl study (Livingston, et al., 1976; Livingston, 1984).

Bay anchovies are year-round estuary inhabitants with a wide range of tolerance for both salinity and temperature (Daly, 1970). They make no long-distance migrations, and spawn all year within the bay, most intensely from spring to fall with a mass spawning peak in May. As eggs and larvae, anchovies are also dominant in the near surface ichthyoplankton. In a survey conducted in 1973-74, anchovy eggs made up 92% of the total eggs caught, while 75% of all larvae were anchovies (Blanchet, 1979). There is year-round recruitment of juveniles into the adult population, with no defined seasonal growth pattern; however, the anchovy population is highest in the summer and fall.

Although they do occur bay-wide and year-round, anchovy distribution corresponds to seasonal changes in freshwater inputs to the bay. In winter and spring anchovies are most abundant in East Bay and eastern Apalachicola Bay (Livingston, 1983). In May there is a concentration off Nick's Hole on St. George Island. Anchovies are again most abundant from June through August in East

Bay. Through the fall they congregate near the Apalachicola River mouth. Anchovies therefore tend to be more abundant in the parts of the bay that are less saline.

The bay anchovies' pelagic life style is reflected in their diet. As very young larvae they consume planktonic copepod nauplii, copepodites, and copepods (Detwyler and Houde, 1970). In Apalachicola Bay, Sheridan (1978) found that bay anchovies consume primarily calenoid copepods (mostly Acartia tonsa) and show minimal ontogenetic feeding changes. Diet changes somewhat among two size classes: the 10-39 mm standard length (SL) group consumed mostly calenoid copepods; the 40-69 mm SL group ate fewer calenoid copepods and consumed large zooplankters such as mysids, insect larvae, and larval and juvenile fish. Seasonally the diet changed as well, with mysids most important in the winter, and copepods predominant the rest of the year. Food items chosen were related partially to the salinity - more insect larvae, mysids, and cladocerans were eaten near the rivermouth, while chaetognaths and barnacle nauplii were eaten at more saline locations.

Anchovies themselves are an important food item for piscivorous fish in the bay (Sheridan, 1979). One of their main predators is the sand sea trout, Cynoscion arenarius. These predators enter the bay as juveniles in April and are abundant all summer when the anchovy population is high. The sand sea trout diet consists of 62% juvenile fishes and 26% mysids (Sheridan, 1979). The bay anchovy made up 78% of identifiable fishes consumed.

2. Mullet

Two species of mullet inhabit Apalachicola Bay, one of which is of commercial and ecological significance. The striped, or black mullet, *Mugil cephalus*, is the most abundant of all fish landed commercially in Franklin County (Table 5). Relatively few silver mullet, *M. curema* are harvested from the bay. Mullet are pelagic schooling fish caught in great numbers commercially in gill nets (long nets which are played out in a circle from a boat to enclose an entire school). Mullet are fast swimmers and are good at avoiding most trawling gear. Their feeding ecology, seasonal and spatial distribution and other life history aspects have not been reported on as extensively as those of the bay's sciaenids or anchovies (Livingston, et al., 1976; Livingston, 1980; 1983).

Mullet spend most of their lives within the estuary except for annual spawning migrations to the gulf. Striped mullet spawn from October through February, with peak activity from November to January (Futch, 1976). The location of spawning grounds off the barrier islands is not known; elsewhere in the gulf, spawning groups have been observed inshore (Breder, 1940), and as far offshore as forty to fifty miles, and in water as deep as 900 fathoms (Arnold and Thompson, 1958; Anderson, 1958). Mullet migrate to their spawning grounds in large schools.

During spawning the females shed their eggs into the water and these are fertilized by accompanying males. An adult female may produce from 1.2 to 2.7 million eggs in one spawning (Futch, 1976). The eggs are planktonic and buoyant and hatch out between 30 and 50 hours after fertilization, depending upon water temperature. Recently hatched planktonic larvae reach the post-larval stage within a week, and begin to travel toward the estuaries. They remain in protected low-salinity areas and grow to nearly two inches within five months, and over seven inches in one year. At this time they may remain in the estuary and overwinter, while the rest of the mullet population migrates to the spawning grounds. It may take from two to three years for striped mullet to reach sexual maturity. They generally become available to the fishery during their second year. Striped mullet may grow to lengths of over two feet and live from six to seven years. They are able to tolerate a wide range of salinities and have been found in the upper reaches of rivers (Futch, 1976).

In Apalachicola Bay most mullet move out of the estuary during winter months, although some may overwinter in the deeper parts of the bay (W. Miley, personal communication). Returning in the spring, they become abundant in summer and fall. They may be found bay-wide, but are caught primarily on the bay side of the barrier islands. Mullet have their best flavor in summer and fall when they become fat and are preparing for their spawning migration; during the winter they consume a lot of mud and may take on a muddy taste. Mullet may also take on a less desirable flavor when they inhabit freshwater. In the fall mullet are sought after for their roe. The main type of gear used to harvest mullet is a gill net, or, when the fish are mixed sizes in spring, the trammel net is used. Cast-nets and small bank-anchored gill nets are often used by individuals, but not on a large scale or for commercial purposes.

Larval mullet and small juveniles eat zooplankton. Larger juveniles and adults are herbivorous and feed by sucking up surface layers of muddy bottoms, or by grazing (Futch, 1976). They consume mostly benthic diatoms and dinoflagellates, plant detritus, and sediment. Mullet are able to retain finer sediment particles and reject larger ones, probably using to advantage any adsorbed bacteria, other microbiota, or organics. When plankton blooms are available, usually in spring and fall, mullet will feed on them (Futch, 1976).

3. Flounders

Flounders, or flatfishes, begin their larval existence with their physical features placed symmetrically on the body. At very small sizes, they undergo a metamorphosis and one eye migrates to the other side of the head, the mouth shifts position, and the internal organs become rearranged. Two families of flatfishes are "left-handed," with their eyes, mouth, and coloration on the left side: the commercially important flounders, Bothidae, and the tonguefishes, Cynoglossidae. Another flatfish family, the soles, or Soleidae, is "right-handed."

Flounders are the second most abundant finfish landed in Franklin County (see Table 5). All commercial flounders occurring in the gulf are bothids, primarily of the genus Paralichthys (Hoese and Moore, 1977). In the Apalachicola area, the two most abundant commercial species are the southern flounder, *P. lethostigma*, and the gulf flounder, *P. albigutta*. The landing category of "flounder" therefore includes more than a single species. Many other species in the bothid family do not get very large as adults. They appear frequently in shrimp catches and are mistakenly considered "baby flounders" (Hoese and Moore, 1977). Other bothid species, in addition to the southern and gulf flounders, have also been collected in the long-term trawl survey, including the fringed flounder, *Etropus crossotus*, the ocellated flounder, *Ancyclopsetta quadrocellata*, the black-cheeked tonguefish, *Symphurus plagiusa* and the soles: the hogchoker, *Trinectes maculatus*, and the lined sole, *Achirus lineatus* (Livingston, et al., 1977).

These flatfishes are primarily benthic, lying buried in the sediments when at rest. They are cryptically colored and are able to alter the intensity of their skin pigment, blending well with their background.

Relatively little is known about the life history of most bothids, particularly in the northeastern gulf, in spite of their commercial significance. The following observations on the southern and gulf founders were made in Texas (Hoese and Moore, 1977):

"Young southern flounder, *P. lethostigma* are found in shallow bays, even in low salinities. The larger fish leave the bays for the open gulf during the fall in order to spawn. A severe norther will cause a mass migration, resulting in excellent floundering or gigging, while a moderate or warm winter will cause the large flounders to leave dispersed over a greater period of time and result in decreased sports and commercial catches. This fish has been called the "mud flounder." In the gulf as well as in the bays this species is often more common over the softer mud bottoms. Large individuals of this species are often called 'halibut.'"

"Like other Texas species of Paralichthys, young gulf flounder are found in the bays during the spring and summer and migrate to the gulf with the onset of colder weather. Ginsburg (1952) called this flounder, 'sand flounder,' since the adults appeared to be more common on hard, sandy bottoms. In the bays the young are found in grassflats."

The feeding habits of the southern flounder in Barataria Bay, Louisiana, were investigated by Fox and White (1969). Analysis of the stomach contents of 305 P. lethostigma collected between 1963 and 1968 was performed. Of the 305 fishes, 134 stomachs were empty. In the other 171 stomachs, fishes made up 93.7% and crustaceans 5.9% of the total food volume, with juvenile mullets and anchovies being the most important food species. The fat sleeper, Dormitator maculatus was extremely abundant as a food item, but in only one collection. Shrimp (Penaeus spp.) and crabs (Callinectes spp.) were the most abundant crustacean food items. Other fish and crustacean species, and unidentifiable remains were found, but made up very small percentages of the total. In fishes of increasing size, no preference for larger food items was noted, but there was an increase in the number of items per stomach. Additionally food items in the flounder stomachs were found to be related to the seasonal availability of such food organisms in the sampling area.

In Apalachicola Bay, both the southern flounder and the gulf flounder are important commercially and have been collected in the long-term trawl survey, but _P. lethostigma_ is usually more abundant because it is found in the bay year-round and _P. albigutta_ is not. The following information on flounders was obtained from W. Miley, Manager, Apalachicola National Estuarine Sanctuary (personal communication).

Adult southern flounder, _P. lethostigma_ are caught commercially throughout the year in Apalachicola Bay, but are less abundant in winter because most adults undertake a spawning migration to the gulf in late fall. As described for Texas southern flounder (Hoese and Moore, 1977), the large flounder will leave the bay for gulf spawning sites over a greater period of time with the onset of a warm or moderate winter, whereas severe temperatures can result in a mass migration to the gulf. Post-larval southern flounder appear in the marshes in early spring. Upon returning to the estuary in spring, the adult southern flounders spread out over the entire bay and up the Apalachicola River as far as Jim Woodruff Dam (Yerger, 1977).

The gulf flounder, _P. albigutta_ spends much more of its time out in the gulf. Adults migrate out of the estuary to spawn in late fall and are not found in the bay during the winter. From

February to April huge numbers of returning adults may be found at staging areas outside the inlets and passes, apparently in anticipation of some change in temperature, salinity, or other factor, before entering the bay. Females caught in these areas are found to have already shed their eggs. The post-larvae of the gulf flounder also move into marsh nursery grounds in early spring.

These two flounders are omnivorous, consuming a variety of organisms, but do prefer to eat fishes. The arrival of *P. albigutta* at its staging areas coincides with the migration to the bay of large numbers of silversides, *Menidia peninsulae*, a preferred food item.

4. *Croaker*

Croaker, *Micropogonias undulatus*, has been the second most abundant fish species collected in the long-term trawl survey (>26.0% of the total fish caught) and is also a popular food fish landed commercially in Franklin County (Livingston, et al., 1977; Livingston, 1984; and see Table 5).

Croaker is an estuarine-dependent, benthic species with a wide tolerance for temperatures and salinities, yet is found in greatest numbers in Apalachicola Bay in salinities below 10-15 ppt (Livingston, et al., 1977). Adult croakers begin to leave the bay on their spawning migration between June and October. They spawn fairly close to inlets and passes from late fall to early winter along the Gulf Coast.

Larval croakers hatch from planktonic eggs and begin developing as they are transported towards the estuaries by tidal currents. They arrive inshore as post-larvae and are most prevalent near the bottom during the daytime (Weinstein, 1980). Blanchet (1979) only found croaker post-larvae in an unusual circumstance, when the sampling net was drawn through the boat's prop wash that had stirred up bottom sediment.

Post-larvae inhabit the shallow marshes, growing rapidly during the late fall and winter months when the highest quantities of detritus and related peaks of detritivorous organisms are present in the bay. Juvenile stages of croakers show up in collection in October and November, and are most abundant in the peak months between January and April (Livingston, et al., 1977).

Juveniles remain within the estuary during their first summer and move offshore in cold weather. They leave the bay again the following summer to spawn. Adult croakers may remain for several years out in the open gulf after their first spawning migration (Parker, 1971; Fruge and Truesdale, 1978).

The majority of croakers collected in the bay are juveniles. During January, they congregate in greatest numbers near the rivermouth and in upper East Bay, when greatest river flow occurs (Livingston, 1983). By February they have spread out throughout East Bay and northern Apalachicola Bay. Over the following few months, as they grow and develop, they move further out toward the barrier islands and from July to September migrate from the bay (Livingston, 1983).

Croakers are benthic omnivores with a diverse diet. Larvae and post-larvae consume primarily zooplankton. Juvenile and larger croakers' food habits were examined in a study of sciaenid trophic resource utilization in Apalachicola Bay (Sheridan, 1979). Polychaetes formed the basis of the diet at 32% of weight for all size classes. Other major components of their diet were detritus (16%), juvenile fishes (8%), mysids (7%), and shrimp (7%). Three feeding groups were found. Small croakers ate polychaetes, insect larvae, amphipods, and harpacticoid and calanoid copepods; the mid-sized group consumed polychaetes, more detritus, and mysids; and the larger fishes tended to specialize upon one or two food items such as polychaetes, infaunal shrimp, and/or juvenile fishes (Sheridan, 1979).

5. Spot

The spot, *Leiostomus xanthurus*, is an abundant fish in the Gulf of Mexico, common in most estuaries. It is the fourth most abundant trawl-susceptible species in Apalachicola Bay, making up approximately 5% of the total collected (Livingston, et al., 1976; Livingston, 1980; 1983), and is also landed commercially in Franklin County (Table 5).

Spot are estuary-dependent fishes with the ability to tolerate wide temperature and salinity variations. They have an annual migration cycle: in late fall and winter adults and first-year juveniles move to spawning grounds in the relatively warmer waters of the gulf, often at great depths and great distances from shore (Pearson, 1929; Fruge and Truesdale, 1978). Most first-year spot develop to sexual maturity during the migration to the spawning grounds (Pacheco, 1962). After spawning, adults travel back in the late winter and early spring to use the estuary as a feeding ground. Eggs and larvae are planktonic and drift shoreward with tides and currents; the developing young have reached the postlarval stage (0.5 inches) by the time they arrive in the estuary.

Post-larvae and small juveniles begin to appear in Apalachicola Bay in January and inhabit the shallow marsh areas of East Bay and Nick's Hole (Livingston, 1980; 1983). They reach peak numerical abundance in March and April. By late summer, the juveniles have grown to near-adult size and the offshore migration begins.

The spot is an omnivore and consumes the animals and plant matter found in the soft sediments of Apalachicola Bay. A study of the spot's feeding habits found that its diet includes many detritus-eating benthic invertebrates such as polychaetes, nematodes, bivalves, and harpacticoid copepods (Livingston, 1983). It was also determined that there was little variation in food habits between size classes - as the fish grew and developed, their food choices did not change (Livingston, 1983).

6. Spotted Seatrout, or Speckled Seatrout

The spotted seatrout, Cynoscion nebulosus, also called speckled seatrout, is an important commercial species landed in Franklin County (see Table 5). It is caught with gill nets and beach seines, and is an extremely popular sports fish, well liked for its flavor and its fighting ability. It was not an abundant fish in the long-term trawl survey, being a relatively fast swimmer. Therefore the following information on spotted trout has been drawn from a fishery profile of the Gulf States Marine Fisheries Commission using data from all the gulf states (Perret, et al., 1980).

Spotted seatrout have an extended spring and summer spawning period from February-March to October, peaking from late April to July. In Florida, spawning takes place in the quieter parts of bays unaffected by tides, in the deeper channels and holes adjacent to vegetated shallow areas. In some parts of the gulf spotted seatrout spawn just offshore of the barrier islands.

Spotted seatrout eggs are buoyant in salinities over 30 ppt, and sink in salinities below 25 ppt. It is unknown exactly where recently-hatched larvae go, but post-larval individuals eventually appear over shallow grassy bottoms where they remain and grow rapidly. After 6-8 weeks, the young seatrout begin schooling. They travel in groups of 5-50 individuals until the ages of five or six, when large females become solitary, usually because of mortality in the other individuals. During the warmer months the juveniles can be found in or near vegetated areas, while adults are more likely to be in deeper water nearby. When temperatures begin to decline, both adults and juveniles are driven to deeper waters in the bays, and larger fish may even enter the gulf or rivers. Spotted seatrout are most abundant in spring when they migrate from their wintering areas to the shallows to feed or to spawn.

Spotted seatrout, both juveniles and adults, are often found in turtle grass, and shoal grass: They are also found in numerous other habitats in the northern gulf, around submerged and emergent islands, shell reefs, marshes, and oil platforms. Tabb (1958) assembled a number of habitat characteristics favorable to seatrout. These included: large areas 10 to 20 feet deep adjacent to the grassflats for refuge in winter cold, an abundant food supply including grazing crustaceans and small fish, an absence of predators and competitors, and suitable temperatures of 59 to 80°F. Spotted seatrout are able to tolerate variations in salinity as extreme as 0.2 to 75 ppt, however, their ideal range is from 20 to 25 ppt. Generally, spotted seatrout spend their entire lives in the estuaries, but they may migrate to the gulf adverse conditions such as low salinities (5 ppt) or low temperatures.

Spotted seatrout may be considered opportunistic carnivores that undergo several ontogenetic changes in diet as they grow to maturity. Their food items are apparently based upon availability since their diet changes with seasons and from one location to another. Numerous studies along the Gulf Coast have found a variety of items taken, with some generalizations possible: post-larvae consume copepods, and as they develop, add small benthic invertebrates to their diet, then larger invertebrates as they continue to grow. Gradually, small fishes are eaten in addition to invertebrates, and ultimately fishes are consumed exclusively.

7. Sand Seatrout

The sand seatrout, *Cynoscion arenarius*, has a similar life cycle to its relative, the spotted seatrout, yet prefers a more muddy-bottom habitat. Like the spotted seatrout, sand seatrout is a very popular sports fish (Table 5). It is very common in other estuaries of the northern gulf and, like most estuarine-dependent fish, has wide salinity and temperature tolerances. It is caught most often at temperatures between 20 and 35°C (Livingston, 1983).

Spawning of sand seatrout takes place in early spring in the Apalachicola area, just offshore of the barrier islands; however, some spawning may take place within the bay (Blanchet, 1979). Larvae are transported by tidal currents through the inlets and passes. By April and May, post-larvae and the smallest juveniles are collected, concentrated in upper East Bay and near the rivermouth. Peak abundance for all juveniles occurs between May and July, and they are found bay-wide. From July to September juveniles are most abundant near the rivermouth and throughout the northern part of Apalachicola Bay. Adults are present from March through December with peaks between summer and early fall. In October, sand seatrout begin to move to warmer offshore waters to spawn, most are gone by November, and from January to March very few are present in the bay at all (Livingston, et al., 1977; Livingston, 1983).

A study of food habits of several fishes of Apalachicola Bay revealed that sand seatrout are water column predators, consuming primarily juvenile fishes (62% of items found in stomachs) and mysids (26%)(Sheridan, 1979). Of all identifiable fishes consumed, bay anchovies made up 78% of the total. Anchovies are the most abundant fish species in the bay, and are available year round (see section on anchovy life history). Juvenile anchovies reach peaks of abundance in spring when juvenile seatrout become abundant in the area. The smallest sizes of sand seatrout rely mostly on mysids and calanoid copepods particularly in shallow, low-salinity areas, but switch quickly to a diet of fish as they grow (Sheridan, 1979). This study indicates that sand seatrout choose food items primarily based upon their availability in the water column.

8. Red Drum

Red drum, *Sciaenops ocellata*, locally called redfish, is one of the most popular sports fish caught in the Apalachicola Bay area. It is also caught commercially by bay fishermen in gill nets (Table 5). There is relatively little data available on redfish abundance and distribution within Apalachicola Bay because it was not collected that frequently in the long-term trawl survey (Livingston, et al., 1977). The following information is drawn from Perret, et al. (1980) from an extensive fishery profile compiled by the Gulf States Marine Fisheries Commission. Where possible it refers to Florida information, otherwise, information is compiled from other Gulf states.

On the Florida coast, redfish spawning takes place from September to February and peaks in October. Spawning apparently occurs offshore, since no ripe females are found in the estuaries. Redfish eggs are pelagic and buoyant, and newly hatched larvae are planktonic and drift to the estuaries with the tidal currents. They arrive inshore as post-larvae from September to December and inhabit shallow, quiet waters over muddy bottoms and among submerged grasses such as shoal grass, and widgeon grass. The young redfish develop rapidly in their first year. Juvenile redfish move from the shallows to the deeper water of bays during their first winter, are most often found near the perimeter of marshes. They tend to be most abundant from January to April. After the first year there is a gradual move to the gulf during cold weather, and a pronounced return into bays and lagoons in early spring. Redfish remain in or near the estuary for two years then, as subadults, move offshore prior to maturation and spawning.

After their first spawning, redfish spend less time in the estuary and more time at sea. Adults may be found in many habitats, over muddy bottoms, sandy substrates, or oyster reefs.

In the northern gulf, adults do not undertake extensive migrations, they usually only travel short distances from bay to gulf.

Redfish are eurythermal, yet are highly sensitive to rapid drops in temperature and may suffer high mortalities during freezes. They are also euryhaline, and their salinity tolerance varies with their age and size; at small sizes redfish are found in low salinity areas while larger sizes usually occur in salinities of 30-35 ppt. Redfish abundance is apparently limited by the total estuarine area available to them. Redfish landings in the Gulf of Mexico, by state, vary directly with the total area of estuaries in each state.

Smaller juvenile redfish consume primarily copepods and copepod nauplii. As they get larger they will selectively eat mysid shrimp when available, and otherwise will consume gammarid amphipods, polychaetes, grass shrimp, penaeid shrimp, and blue crabs. Adult redfish eat decapod crustaceans (crabs and shrimp) and fish. They feed by visual and tactile means, either sucking in their prey or biting into the substrate. Usually, they feed in the early morning or late evening, either on the bottom or in the water column. They will often lie in sloughs behind sand bars and feed during a falling tide.